SESSION 7

REDUCING PESTICIDE WASTE THROUGH IMPROVED MACHINERY DESIGN AND USE (II)

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VALIDATION OF A DECONTAMINATION METHOD FOR ARABLE CROP SPRAYERS FOLLOWING USE WITH THE SULFONYL UREA HERBICIDE - AMIDOSULFURON

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ABSTRACT

Spray solutions can be retained in quantities that will vary with sprayer type and size. Many components that are used as engineering control or safety mechanisms can be identified that contribute to the magnitude of this potential contaminant. Some components are readily cleaned but others hold back liquids until they are next activated - either deliberately by the operator or unknowingly. Failure to remove this trapped liquid can result in contamination levels able to damage a sensitive crop with which it is treated. Approved decontamination methods are effective with amidosulfuron when used alone or in emulsion mixtures with propiconazole or bromoxynil/ioxynil.

INTRODUCTION

It is now a Condition of Approval for agrochemicals that an adequate decontamination routine for sprayers is defined for implementation after field use [EC Directive 414, Annex III]. This need prompted an earlier study which identified where agrochemical solution may be retained within the sprayer and, more recently, the impact - if any - of the binding properties of a sulfonyl urea herbicide to material used in modern machine construction. However, adoption into commercial practice also demands that the logistics of any change are acceptable to operators. Hence, sprayers today carry an adequate volume of flushing water, rinsing nozzles within the main tank and hose with lance to permit speedy decontamination of internal and external surfaces in the field. The effectiveness of these new cleaning systems has to meet the most stringent demands for, with some agrochemicals such as those from the sulfonyl urea group, very low concentrations in subsequent applications can cause crop damage. The recent introduction of amidosulfuron gave the opportunity to simultaneously validify modern in-field decontamination methods.

MATERIALS AND METHODS

The sprayers

Three Hardi tractor mounted and two trailed sprayers which ranged in age and specifications have been used to locate components of the machine which can internally retain spray liquid (Table 1). All the essential components on every sprayer - tank, pump, control manifold and boom - were considered as potential residue traps as well as the more recently introduced pressure agitation, self cleaning filter, induction bowl and container rinse systems. In particular, those points where liquid could be held, perhaps unknown to the operator, and be subsequently released unintentionally were sought. Additional hoses, attached to the end of every boom section, to direct spray liquid back to the main tank, was the only modification made for these research purposes from normal commercial models.

Table 1. The Hardi sprayers used in this study

Year of Manufacture	Model	Tank size; litres	Boom size; meters
1995	LX	600	12
1989	LA	800	12
1997	Master	800	12
1989	TZ	1500	18
1997	Commander	2500	24

Use of traced spray liquid to predict residues

A premixed solution of water with the non-ionic surfactant - Agral (Zeneca Crop Protection Ltd)- at 0.1% with the tracer, fluorescein, was used to simulate a typical spray solution and facilitate quantification of deposits. This liquid was pumped into each sprayer until half filled. The sprayers own pump was then used to circulate the liquid with agitation, ensuring the pressure relief valve was operated, some spraying and, where fitted, the induction bowl, container rinse and self cleaning filter systems. This liquid was then pumped back to the bowser until the liquid pressure dropped; a sign that the tank cannot be drained for further air is being induced. The tractor engine was stopped to minimise shaking of pipes and other surfaces of the sprayer. On one occasion with the Master, we further drained the sump by opening the drain valve to permit that comparison to be made.

A known volume of clean water was poured rapidly into the main tank from an overhead supply. Samples of the resultant liquid containing the bulk of the tank's residues were taken. On one occasion, samples were extracted at varying depths through thin capillary tubing immediately after adding the water, one and 23 hours later, to gauge the speed at which a stable uniform mix is reached. This precaution we thought was necessary since all sampling would be from within the tank. Indeed, the first sample is taken without the advantage of mechanically induced agitation. The tractor was restarted and pump rotated to ensure thorough washing of its internal surfaces and associated pipework. Further samples were taken for fluorometric analysis. Every other function was also used in turn with sampling taking place at every stage.

Validation of decontamination methods following amidosulfuron use

Only the Hardi Twin sprayer [Model LA] was used with active ingredients for earlier traced data was shown to make good predictions of likely residue levels. This machine was fitted with an 80 litre flushing tank and internal rinsing nozzles. The 800 litre main tank was half filled with water and amidosulfuron added to make a 400 ppm solution. The liquid was left in the tank with full agitation whilst directing the spray through the booms back to the main tank for 15 minutes. In this manner, the inner surfaces of the tanks walls and pipes were exposed to the active for a typical time scale met during field use. Wetting and rewetting of the upper tank walls would further

encourage potential build up of any residues. The amidosilfuron solution was then pumped out to a holding bowser until, as before, the pressure dropped. The sprayer was left an hour to allow further drying and reproduce the practice of what could take place on commercial holdings. Decontamination followed the typical farmer practice of double rinsing and two further methods which involves the use of All Clear Extra or domestic bleach; the latter techniques being already associated with cleaning after sulfonyl urea use. These cleansing agents, which may also deactivate herbicides of this structure, are used to soak a filled sprayer for 15 minutes as a further stage between the two additions of flushing water. The final residue concentrations were determined after thoroughly washing all exposed sprayer surfaces with 400 litres of water in which 20 litres of "blank" Nortron had been dispersed. Samples were then taken for HPLC chemical analysis.
In addition to the use of amidoslfuron alone, this active was also used in two further mixes with either propiconazole [as Tilt 250 EC] or bromoxynil/ioxynil [as Deloxil]. The extension of this study to include these emulsifiable concentrates was due to a general concern that they could increase the tenacity of the sulfonyl urea to internal structures and thereby pose a greater threat to that when used alone.

RESULTS

Care does have to be taken when sampling a non-agitated solution even though the water was dropped at great speed into the tank and there was considerable turbulence (Table 2).

Table 2. Uniformity of samples from varying depths within a spray tank when taken at three time intervals after water was added; mls of original traced spray solution

		+0	+1	+23
Time from adding water; hours		+0	+1	+23
Tank location;	Top	0.418	0.505	0.664
		0.407	0.498	0.585
	Middle	0.515	0.504	0.576
		0.841	0.520	0.703
	Bottom	4.984	1.831	0.600
	Sump	6.256	Not sampled	

Concentrations were greater at the bottom of the liquid because, we believe, some seepage from connecting pipes may take place - a concern that is not relevant to later sampling in each sequence. Residues in the booms were measured with the three older Models only (Table 3). The variation

Table 3. Boom residues; litres of original traced solution

Model;	LX	LA	TZ
	1.9	9.4	17.7

Table 4. Total residues within five Models of sprayer but not that in booms and their supply pipe; litres of original solution

Model: LX	LA	Master – before and after sump drainage		TZ	Commander
8.0	9.6	8.7	6.2	27.7	23.0

shown is attributed to supply pipe length and boom width differences. Total residues in the complete machine, but not including the booms and their supply pipes, ranged from 8.0 to 27.7 litres (Table 4). Sump drainage with the Master may remove a further one or two litres after spraying has to stop through lack of liquid pressure.
A total of seven distinct component systems can each independently contribute to the total residue within a modern sprayer. Tank, pump, induction bowl and booms dominate; contributing some 26, 23, 17 and 26% of the total respectively (Table 5).

Table 5. The quantity, location and concentrations of spray residues within components of a Hardi LA sprayer; litres of spray solution [predicted* ppm of amidosulfuron]

Component	Residue	Predicted ppm
Tank	9.9	4.95
Pump and associated pipes	8.5	4.25
Pressure agitation and pipes	1.3	0.65
Manifold and pipes	0.3	0.15
Self cleaning filter pipe **	1.5	0.75
Induction bowl with container rinse	6.4	3.20
Booms and pipes	9.4	4.80
Total	37.3	18.8

* Predictions assume amidosulfuron was used at 400 ppm in original solution.
** Pipe contents after pressure relief valve.

Use of infield cleaning systems will substantially reduce residue levels after two flushing stages have been used (Table 6). Typically, the volume of water used is 10% of the main tanks capacity but can be more.
Amidosufuron analysis was measured in the LA sprayer when no cleaning had taken place. On the assumption that the tank was filled with 800 litres of water then this next solution would have been contaminated at 12.0 ppm - a concentration likely to cause damage in sensitive crops with this first load (Table 7). Following the double water rinse, retained quantities of active could be capable of producing concentrations of 0.4 ppm whilst both All Clear Extra use or bleach were even more effective for none was detectable. Mixtures of amidosulfuron with either of the emusifiable

concentrates in solution, failed to change these values. The HPLC analysis for the unwashed sprayer was 12.0 ppm whilst the earlier traced studies had predicted 18.8 ppm. Although there is some discrepancy between the two techniques, we do not believe the value of the data generated with fluorimetery should be reduced.

Table 6. Residues within sprayers following a two stage flushing routine

Model	LA	Master
Main tank capacity; litres	600	800
Flushing tank capacity; litres	120*	84**
	Volumes of original spray solution; litres	
Total at start	15.9	8.7
After first rinse	3.0	4.9
After second rinse	0.2	0.8

* Flushing water used in two 60 litre batches
** Flushing water used in two 28 litre batches

Table 7. Amidosulfuron concentrations after varying decontamination methods
Measured concentration in 800 litres of water; ppm

No cleaning	12.0
Double water rinse	0.4
All Clear Extra	nd
Bleach	nd

Knowledge gained earlier with decontamination studies has led to some features now being incorporated into the latest designs. Thus, with the Commander for example, the sump is most pronounced and there are bleeds within pressure restrictor valves that avoid trapping points for spray solution. The consequence of these improvements is to further improve onboard decontamination capabilities. Following a two stage internal cleaning routine which used 180 litres of water, left a mere 91 mls of original solution; about half being left in the pipes associated with feeding the manifold at the rear of the sprayer (Table 8).

Table 8. The volume and location of spray residues within a 2500 litre trailed Commander

Sprayer component*	Original spray solution; mls
Pump and relief valve	5.35
Control unit	9.12
Manifold	44.78
Induction bowl	18.07
Total	91.21

*Components include their associated pipes.

CONCLUSIONS

Spray solutions retained in tanks, pumps, booms and control systems whilst contributing greatly to the total residue within sprayers, are unlikely to pose a major problem through faulty decontamination methods. All such components would be flushed as soon as the pump was used and the operator opened the boom control valves. Crop damage may occur from the first tank load but is not so likely with subsequent ones. However, it is possible to hold back spray solution in other areas yet still use the sprayer normally. If the operator failed to open the pressure agitation, pressure relief, induction bowl and container rinse systems during his cleaning routine, then he may carry sulfonyl urea solution indefinately as a potential contaminant. Concentrations in excess of 0.4 ppm - which may be sufficient to damage a sensitive crop such as sugar beet - could be exceeded.
Rinsing of these sprayers with water and the two cleaning/deactivating agents were effective but operators must remember to clean all internal surfaces including those system components that protect the machine and the operator or are fitted as accessories.

ACKNOWLEDGEMENTS

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A SURVEY TO DETERMINE THE AMOUNT OF UNUSED PRODUCT AND DISPOSAL METHODS USED IN PESTICIDE APPLICATION.

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ABSTRACT

An investigation was carried out on 85 farms in the Po Valley (55 cereal-growing and 30 orchard farms) to assess the disposal methods used for spray mixture that remained in the tank at the end of treatment and for rinsing water used during sprayer cleaning. The way in which pesticide containers were stored and then disposed of was also analysed. The amount of mixture that remained in the tank at the end of treatment was lower in the case of boom sprayers with an average of 2.4 l compared with air assisted sprayers which had an average 14 l. In cereal-growing farms an average of 60 l of chemicals were stored, while on fruit-growing farms the quantity was near 90 l. The empty containers on both types of farms were mainly burned, while only a small number of farmers (3%) provided for their collection by specialised firms. The analysis pointed out that farmers do not correctly dispose of chemical product not sprayed mainly because of a lack of technical information.

INTRODUCTION

Today, the growing of crops is based on the use of pesticides, which, apart from their useful effect against pests, may represent a potential risk to the operator and for the environment. Application equipment and operating conditions have a decisive effect on product efficacy as does an even, correct application of the chemical. Over or uneven dosing, unintentional disposal of active ingredient and risks of exposure for users are the main problems linked with pesticide use. In particular, incorrect disposal of any pesticide mixture residues, of the water used to wash equipment (Dohrnet, 1993; Ozkan, 1992) and of the empty chemical product containers (Savi *et al.*, 1990; Luciani, 1994) may result in indiscriminate forms of environmental pollution.

Spurred by the concern about hazards and the need to optimize use of pesticides, various countries have specified minimum requirements for field crop sprayers and introduced regulations on product and empty container disposal. In Italy, pesticides are classified (Presidential Decree 915/82) as toxic, harmful waste because of the substances they contain and are therefore regulated by certain constraints on disposal such as the incoming/outgoing register and forwarding to controlled dumps.

A specific survey was made of 85 farms in the Po Plain in order to assess the ways in which this waste water was currently disposed of, to permit more in-depth examination of the quantities involved and to examine the problem of disposing of the containers. In particular, the survey involved 55 cereal growing farmers with an average size of around 35 ha (range from 4 to 190 ha) and 30 orchard growing farms with an average size of 13 ha (range of 2 - 28 ha).

PARAMETERS RECORDED AND METHOD OF RECORDING

To assess the environmental impact of operations closely related to use of sprayers, a questionnaire was distributed to the 85 producers involved in the survey. This aimed at gathering information about the quantity and method of disposal of pesticides remaining in the tank, tank flushing methods and destination of the waste water. To establish the way in which the pesticides were stored, information was collected regarding the rooms used for this purpose: dimensions; type of ventilation; type of flooring; any possibility of collecting the washing water and the possibility of preventing access by unauthorized personnel. Various interviews and inspections were made directly at the farms involved to try and discover the number of pesticide containers present on the farm, the type of material of the containers, the amount of material contained and the year of purchase. Lastly, methods of disposal of empty containers and of the pesticides not used on the crops were also identified.

RESULTS OBTAINED

Quantities and method of disposal of mix residue

In the case of **boom sprayers** (cereal growers), it was found that an average 2.4 l (ranging between 0.5 and 25 l) of mixture (water + pesticide) remained in the tank, i.e. that the pump was unable to remove. In particular, at more than 76% of the grain farmers examined, the residue was less than 2 l and exceeded 10 l only in 2 % of the cases (fig. 1). In most cases (52.7%), this pesticide mix was regularly poured (fig. 2) onto the ground near the farm buildings whereas in 25% of the cases it was recovered for use in subsequent treatments, for weed killing on banks or in farmyards.

In the case of **air assisted sprayers,** the residual pesticide left in the tank at the end of treatment was equal to an average 14 l (range 1.5-21 l). At 59% of the orchard farms examined, this liquid was left in the tank and re-used in the next treatment. In 19% of the cases, it was disposed of in the field with a further pass of the spraying machine. In 19% of the cases it was disposed of regularly close to the farm buildings and in 3% of the cases it was recovered from the tank and re-used subsequently. Considering that the cereal growers surveyed usually carry out an average of 4 treatments/year and the orchard growers 8 treatments/year, the farmers have to dispose of between 10 and 112 l/year of pesticide respectively.

Figure 1. Total volumes of chemical residue in the tank on cereal farms

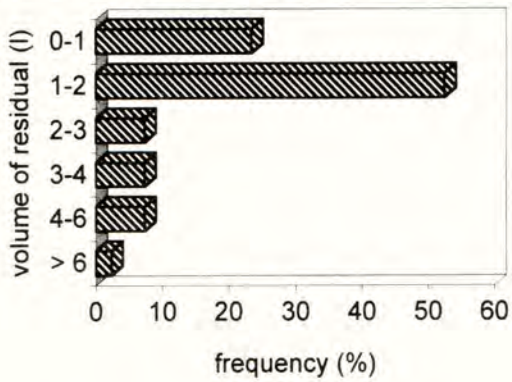
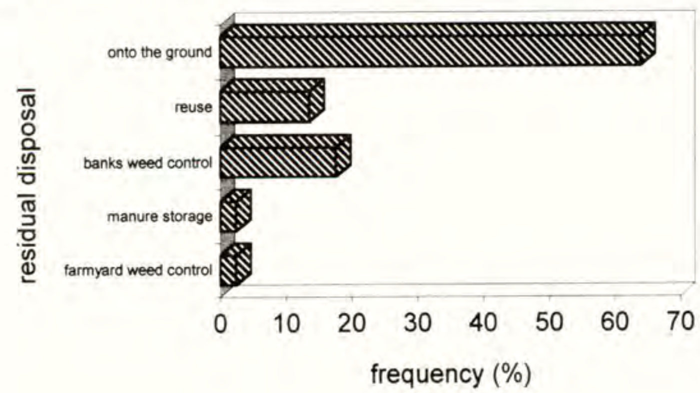


Figure 2. Methods of disposal of spray residues used on cereal farms



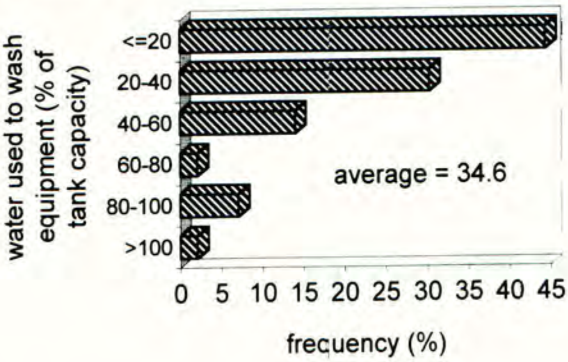
<u>Methods of washing equipment and disposal of waste water</u>

In the case of **boom sprayers**, the equipment was usually washed (around 95% of the cases) only at the end of the treatment and very few farmers (less than 4%) washed the equipment at the end of each working day. The machines were washed at the farm centre usually in areas without any type of flooring (87.3% of the cases) and using only water (80% of the cases) while only 12% of the farmers surveyed also used detergents. The average amount of water used to wash equipment was close to 35% of tank capacity (fig. 3). The water used for washing was generally poured directly on the ground (87% of the cases); alternatively, it was also used for weed killing on banks (1.8% of the cases) and poured into the drains (3.6% of the cases).

In the case of **air assisted sprayers**, 30% of the persons interviewed declared that they washed the equipment at the end of each treatment and 34% only at the end of the season. Detergents were used in only 20% of the cases. In 66% of the cases examined, the sprayers were washed in floored areas and in 45% of the cases these areas were also equipped with a system for collection of the water. The amount of water used to wash the equipment was lower than that recorded for the boom sprayers and equal to 15% of tank volume. This difference can be attributed to the larger size of tanks (2200 l) compared with those of fitted to boom sprayers (950 l).

Considering four treatments/year for the cereal growers and eight treatments/year for the orchard growers and washing of the sprayer at the end of the treatment only, the farmers would need to dispose of 1300 and 2600 l/year of washing water respectively.

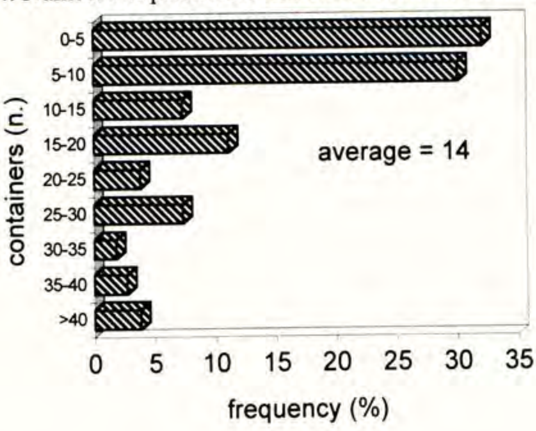
Figure 3. The amounts of water normally used for tank washing by cereal farmers



Methods of pesticide and container storage and disposal.

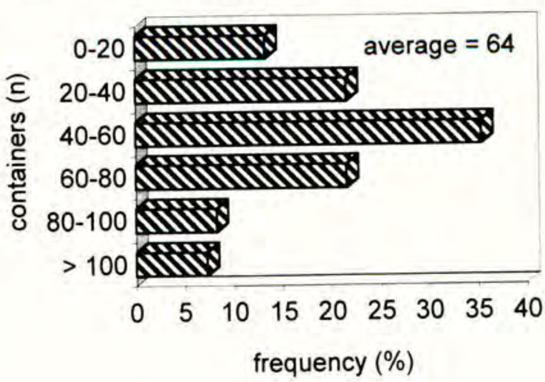
Cereal growers kept an average stock of 14 containers of pesticides. In particular, at most farms (62%), there are less than 10 containers in the storage area while less than 8% of these have a storeroom with more than 30 containers (fig. 4). These have an average capacity of 8 l with a range of variation between 1 and 50 l and, with regard to the material in direct contact with the product, 14% were of aluminum and 86% were of plastic. It was found that the containers in the storeroom had been purchased from 1989 onwards; in particular, more than 64% of these had been purchased less than two years ago. On average, just less than 60 litres of various types of pesticides were stocked on the farms. More than 53% of the containers stocked in these areas were empty waiting to be disposed of.

Figure 4. Numbers of pesticide containers stored on cereal farms.



The **orchard growers** kept an average stock of 64 containers of pesticides. In particular, 66% of the farmers kept a maximum stock of 60 containers and less than 7% of farmers a stock of more than 100 containers (fig. 5).

Figure 5. Numbers of pesticide containers stored by orchard growers.



The material in direct contact with the chemical product was plastic in 81% of cases and the rest were of metal. More than 60% of the containers had been bought less than 2 years ago and had a capacity of between 0.25 and 25 l. Around 8% of these were empty waiting to be disposed of, 80% were full and the remaining 12% opened.

The pesticides were stocked in areas not fully compliant with operator safety with regard to the toxicity of these products. In particular, the pesticides were stored in rooms with an average volume of 95 m^3 in the case of the cereal growers and of 45 m^3 in the case of the orchard growers. In all cases examined, these areas were not specifically constructed but set up inside storerooms, agricultural machinery sheds or in old buildings no longer used. At both types of farm, most (90%) of the areas in which the pesticides were stored were equipped with just an opening able to insure natural ventilation and not with the equipment required for fast extraction of the vapours or dust released if the containers were to break. In almost all cases, (more than 90%) the floor consisted of a cement slab or of tiles. Only at eleven farms was the floor constructed in such a way as to assure fast, complete removal from the area of any chemical product that leaked from the containers and of the water used for washing. This water is often poured directly on the ground or routed to a draining well or to the farm manure heap. In all cases, the solutions employed cannot be considered optimal with regard to the environment.

The only main difference recorded between the two types of farms examined refered to the locking of the areas where the pesticides were stocked. This is mandatory for preservation of first and second class products and was present at only 56% of the cereal farms and at almost all (93%) of the orchard farms.

With regard to the disposal of the empty containers, this depended mainly on the type of construction material. On cereal farms, around 10% of the containers were stored while awaiting changes in the legislation on this subject. The remaining portion were either burnt, as in the case of paper and plastic containers which account for 56% of the total, disposed of as urban waste (20% of the cases), or sent to scrapping firms in the case of metal containers (4% of the cases). Some farms disposed of these containers either on the manure storage (7% of the cases) or sent them to a specialized collection centre (2% of the cases) (fig. 6). In the case of the orchard farms, some (7%) of the farmers stocked the containers while awaiting changes to current legislation. With regard to the other cases, containers made of paper and plastic were burnt (97%) while metal containers were sent to disposal companies (59%), to municipal wastes dumps (7%), buried in the fields (7%) or re-used for other purposes at the farm (13%). Only 3% of the containers were sent to specialized collection centres (fig. 7).

At both types of farms, the pesticides, once purchased, were used entirely and therefore do not produce residues to be disposed of. The survey highlighted that the farmer buys these products shortly before the time of use and only a fraction - that exceeding the effective treatment requirements - is preserved for a limited period while waiting for the next crop cycle.

CONCLUSIONS

If, on the one hand, the survey revealed an undeniably non-optimal situation with regard to safeguarding the environment, it also made it possible to quantify, with a certain degree of approximation, the amount of waste products resulting from pesticide treatment of crops.

Figure 6. Methods of disposal of pesticide containers used on cereal farms

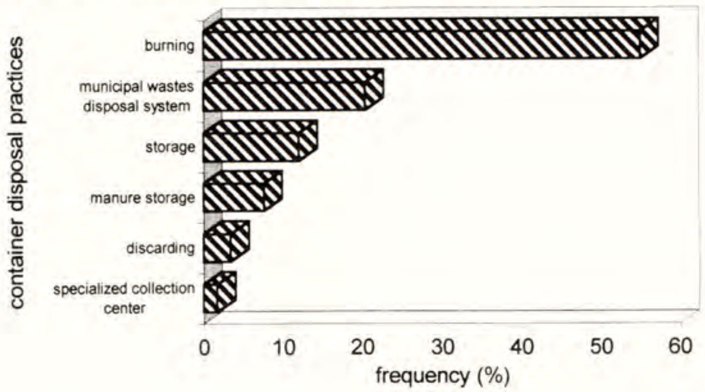
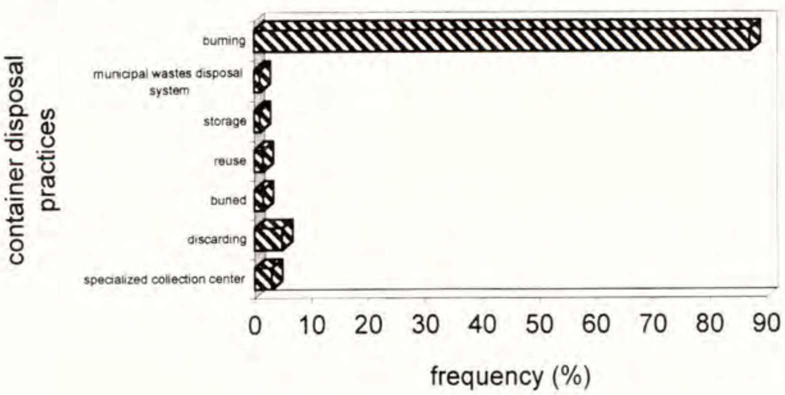


Figure 7. Methods of disposal of pesticide containers used on fruit farms



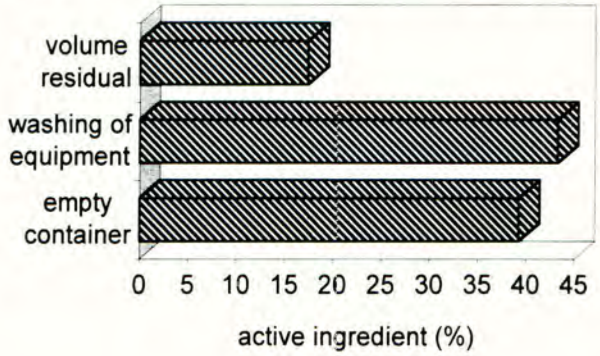
With the most optimistic hypothesis of a single weed-killing pre-emergent treatment of a crop of maize on a surface of 60 ha and considering the results of the survey, the quantity of residue products relating to this treatment is equal, each year, to:

- 18 l of mixture (water + pesticide) left in the tank;
- 1200 l of water coming from washing of the sprayer;
- 72 empty pesticide containers with a capacity of 5 l (corresponding to a total weight of 5.6 kg).

Taking into account the results of other studies of the residues in pesticide containers (Nappi *et al.*, 1994), this results in a total quantity of active chemical of around 1000 g to be disposed of.

This is an extremely small fraction (0.66%) of the total in relation to that distributed on the crop. However if, as in the case of the residual mix and washing waters, it is distributed regularly on the ground, it represents a considerable amount (110 g p.a./m^2 of surface). To avoid environment-related problems, the farmers should use sprayers equipped with tanks for field washing of the equipment. In fact, it is the problem of disposal of this water that represents, in terms of pesticide, the largest fraction of the entire quantity that the farmer must dispose of (fig. 8).

Figure 8. Fraction of the active ingredient that the farmer must dispose of in the various phases.



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SOME FACTORS THAT MAY INFLUENCE RATE OF ACCUMULATION AND FINAL QUANTITY OF PESTICIDE DEPOSITS ON EXTERNAL SURFACES OF ARABLE CROP SPR AYERS

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ABSTRACT

Rate of accumulation of external deposits on sprayers are influenced by spray quality and wind speed but, less so, by sprayer size. The combination of high, localised accumulation rates on angular structures, may lead to run off during spraying. Decontamination in the field of external surfaces can be effective despite the restraints of dual pump use and limited clean water volumes.

INTRODUCTION

Pesticides are typically applied to arable crops using liquids that are sprayed through hydraulic nozzles. After atomisation of this solution, some drops may be deposited on the external surfaces of the applicator to form dried residues. In addition, accidental spillage from supply tanks, leakage's from pipes and closed, vented openings may cause further contamination through wet loading of this equipment. It is believed that these sources of contaminant could pose an environmental and safety threat. Both wet loading capacities, and those factors that may influence the magnitude and accumulation rate of external residue build-up on sprayers, are considered in this paper.

MATERIALS AND METHODS

Sprayers used and application details

Two new but contrasting Models of arable crop sprayers were used. Firstly, the Hardi Master with its 800 litre main tank and 12 metre boom was selected as being representative of the tractor mounted types in common use today. The second Model was a Hardi Commander with a 2500 litre main tank and 24 metre booms - a trailed sprayer popular on larger holdings. Both machines were supplied with flushing tanks that contain clean water that is used, after discharging the spray solution, to flush internal and external surfaces of the sprayer through dedicated nozzles or hose and lance respectively. Both also had induction bowls, clean water containers and hose/reel assemblies.

Flat fan 110 degree Hardi nozzles were fitted to produce Very Fine [411008], Fine [411014] or Medium [411020] sprays at a pressure of 3 bars; spraying speed was 7.2 km/hour [2 m/sec] and the spray liquid was water with the non-ionic surfactant Activator

90 [Newman Agrochemical Ltd] at 0.1% vv. Volume rates increase with drop size - 50, 155 to 270 l/ha - to follow common commercial practice. A fluorescent tracer [fluorescein from BDH Ltd] was added to facilitate the quantification of spray deposits in the water that had been used for spraying or rinsing; samples of the latter were taken and their concentrations determined against known values using a Perkin Elmer filter fluorimeter.

Wet loading of sprayers and their decontamination

A traced solution in the main tank was sprayed, using their hose and lance, to thoroughly wet all external surfaces of the tractor mounted/hitched machines. In this manner, we simulated the maximum loading that is likely to occur through leakage or spills. The booms were then folded and the sprayers positioned over a 1.5 by 18.0 metre catchment pool [a component of the Hardi Scanner kit] containing 300 litres of clean water. A small centrifugal pump recirculated this water through hose to a sprinkler. The unfolded booms and then the rest of the sprayer were washed with the water from this sprinkler to remove the very soluble tracer. Residue values for these two key sections of the sprayer were derived to help identify the most contaminated area; data which may help operator efficiency in the field when cleaning such surfaces. The wheels and hubs of the trailed Commander were not included in this decontamination routine; their residues could be from contact with foliage or soil covering the previously sprayed areas and not as a consequence of the application itself.

Applying external deposits from conventional field use

Conventional spraying took place in an open grassed field with the boom about 0.5 metres above the ground. Applications were made following a set spraying route whereby the operator drove the machine for 50 metres in one direction then turned left at 90 degrees for a further 50 metres. A complete turn was then made and he resprayed the same 50 metre swath before making a further left turn. After 8 discreet 50 metre swaths, this routine had formed an X pattern which ensured the sprayer was equally exposed to the wind from all directions. We observed that whilst the operator did not spray during the turns, he could still pass through the trailing drift cloud. This protocol helped to minimise the impact of wind direction on build up rates yet still reproduced likely commercial practice. Two such circuits were made when a 400 second exposure time was needed. On other occasions, exposure time was recorded up to the moment the sprayer ran out of liquid; the operator stopping when he saw a rapid pressure drop to 1.5 bars. Mean wind speeds during the applications were recorded at a 2 metre height.

Decontamination using Sprayers own Equipment

Both sprayers had flushing tanks with capacities of about 10% of the main tank. Clean water was taken in them to the field and used to decontaminate the outside of the sprayer by pumping it through the system to the hose and lance after the external residues had been applied. Commercial practice was followed where ever possible. Hence, flushing water was used in three batches; using the first two for internal cleaning [followed by it being sprayed out] and the remainder for external washing. During the external washing phase, almost two/thirds of the pumped water from the flushing tanks would reach the main tank. Volumes of water used and operator times were recorded.

RESULTS

Total loading of the Master and Commander Models with the spray solution were about 1.5 and 2 litres respectively (Table 1). The Commanders booms retained almost three times that measured for the Master. Residues on all other areas of the machines were comparable - despite obvious size differences.

Table 1. Total retention of spray liquid by two sizes of sprayer; mls

	Booms	Rest of sprayer	Total
Commander	1248	907	2155
Master	453	991	1444

Using the hose and lance with clean water for 1, 2 or 3 minutes - time equally spent over the complete machine - to remove this solution from the Master sprayer suggests that the bulk of the deposits are readily dislodged (Table 2). After 1 minute cleaning with the hose some 66% is removed; three minutes use removes 82% of the estimated original total. The increased washing efficiency of this further hose use is gained by directing it at the "remainder" of the sprayer and not by further cleaning of the booms.

Table 2. Influence of cleaning time/water volumes on removal of external deposits from a Master sprayer; mls

	Booms	Rest of sprayer	Total
Cleaning time (mins); 1	65	433	498
2	117	241	358
3	84	169	253

Spray quality and wind speed

The Master sprayer was used on two occasions - the first when there was no wind and the second when it was 1.6 to 2.5 metres/second - to apply Very Fine, Fine or Medium spray qualities. Residue values have been normalised to adjust for differing spray water volumes, and therefore the solution concentration, to aid comparisons between the different application methods. Spraying in some wind and applying finer spray qualities [and/or lower water volumes] increases the rate of contamination beyond that of coarser sprays applied in the absence of wind (Table 3). Very Fine sprays may build up deposits four times

Table 3. Rates at which external sprayer deposits accumulate on a Master sprayer during the application of varying spray qualities under two wind speed regimes;
mls of spray solution/hour of exposure/100 litres/hectare applied

Spray quality:		Very Fine	Fine	Medium
Wind speed; m/sec	0.0	720	618	mv
	1.6 to 2.5	1698	801	416

faster than a Medium when spraying in a light breeze. Accumulation rates for external residues on the larger Commander when applying Fine sprays, are similar to that for the Master (Table 4).

Table 4. Accumulation rates of external residues from Fine spraying with the Commander - and its 24 metre boom - on two occasions;
mls of spray solution/hour of exposure/100 litres/hectare applied

Day	Replicate	Wind speed; m/sec	
Day 1]	I	3.0	720
	II	2.0	854
	III	2.0	1132
Day 2]	I	1.8	476
	II	2.3	610
	III	1.7	465

The distribution of external residues between that on the 'remainder' of the sprayer [including main tank, pump, flushing tank, clean water container, induction bowl and hose reel] can be equal to or greater than that on boom structures - irrespective of experimental variables (Table 5).

Table 5. Distribution of external residues over a sprayer;
% of total on booms/remainder of sprayer

Sprayer	Wind speed;	Spray quality;	Very fine	Fine	Medium
Master	0.00 m/sec		78/22	58/41	mv
	1.90 to 2.47		46/54	58/42	53/47
Commander	1.99 to 3.00		mv	58/42	mv
	1.7 to 2.3		mv	75/25	mv

a pulse of liquid will come through the hose which is of the same solution strength as that last pumped (Fig 1). However, a rapid decay in concentration will follow.

Time taken to decontaminate sprayers

Time, from the sprayer running out of enough liquid to sustain adequate pressure, to the operator finishing all decontamination routines, was 13 minutes (Table 9). Six minutes were spent spraying out the two batches of solution that had been used for internal flushing - when 411014 nozzles had been fitted - whilst 4 minutes were spent adjusting the sprayers valves to pull water from the flushing tank and directing it to the various components. Only a further 3 minutes was used to wash external surfaces.

Table 7. The influence of sump drainage - after spraying out – on internal residues measured during the field decontamination routine; litres of original solution [% concentration]

	Main tank	- sprayed out only	- and sump drained
		Rep I	II
Stage 1:	7.59 [33.0]	9.80 [49.0]	6.20 [27.3]
Stage 2:	4.12 [17.9]	5.72 [15.9]	1.95 [8.6]
Stage 3:	1.14 [4.1]	0.55 [3.1]	0.74 [2.6]

Stage 1: Samples analysed after 28 litres of clean water had been directed to main tank and circulated through all sprayer functions.
Stage 2: Repeat of Stage 1.
Stage 3: Analysis based on the 18 litres of clean water directed to main tank - during the external decontamination routine with the hose - to be used for the third and final internal rinse.

Table 8. External residues after completion of internal/external decontamination routines in the field; mls of spray solution

Wind speed during the exposure time; m/sec	0.58	2.99
Booms	22	76
Remainder	52	169
Total	74	245

Exposure times and external residue accumulation

Residues from applying pesticides in the field may not be in exact proportion to the time spent spraying. This apparent lack of correlation may be due, for example, to build up rates that are faster than drying times with resultant drips being lost from wet surfaces. Therefore, in our field protocol when exposure time was not varied, a relatively short time [400 seconds] was used on the basis that subsequent environmental conditions could introduce uncontrolled variables. The data may represent the worse-fit for external accumulation rates. However, on one occasion, the Master was used to apply a Fine spray for 400 seconds and, in a second test, for 800 seconds. Full decontamination over the catchment pool took place after each exposure time. Clearly, if conditions had not dramatically changed between treatments and there was no losses, then residues would be doubled. No such doubling of residues occurred on the booms but did so on the "remainder" of the sprayer when used in a mean wind of 2.71 and 2.37 m/sec. respectively (Table 6).

Table 6. Influence of exposure time on external residues from Fine spraying with a Master sprayer; mls of spray solution

Location of residues;	Booms	Remainder	Total
Exposure time; 400 seconds	162	158	320
800	184	350	534

Use of decontamination equipment in the field

Flushing tanks contain the clean water that is used in the field to decontaminate both external and internal surfaces. However, there are restraints. Total volumes are limited by weight considerations to about 10% of the main tank capacity. In addition, to minimise weight and costs, the pressure to direct this liquid through appropriate pipes and equipment comes from the same pump as that used for spraying. In this study, the existing operators practice was followed of cleaning internal surfaces first then the external – all in the field of use. During this routine, we took the opportunity to measure internal residues and flushing liquid concentrations for both, it can be shown, may influence subsequent external residues. The value, if any, of sump drainage in the field - by opening the main tanks drainage valve - during the decontamination routine was also measured.

Draining the sump, after spraying out, reduced the volume of spray solution retained in the main tank by a further one litre (Table 7). In consequence, the flushing water which had then been used to clean the pump, manifold and induction bowl, was less contaminated too. External residues, after use of hose with the final third batch of flushing water, was dependent on the level of contamination at the start of the cleaning routine - a level, itself, conditioned by wind speed during the spraying (Table 8). Contamination of the cleaning water issued from the hose, after the pump has been used to circulate two earlier batches through the sprayers control system, was also measured (Table 9). After about 20 seconds, Fig 1. Decay in concentration of a pulse of spray solution within the hose used for external decontamination in the field

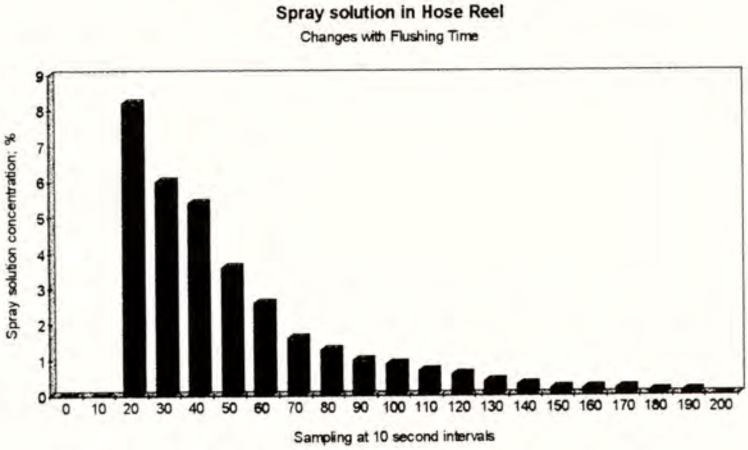

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Table 9. Time taken, and clean water volumes used, during the internal and external decontamination of a Hardi Master sprayer.

	Time; mins	Volumes; litres
First internal rinsing	2	28
Spraying out with 411014 nozzles	2	
Second internal rinsing	2	28
Spraying out with 411014 nozzles	2	
External washing -	3	10
- during which 18 litres are directed to main tank		18
Final spraying out with 411014 nozzles	2	
Total:	13 minutes	84 litres

CONCLUSIONS

Liquid volumes that can be retained on external surfaces of medium and large sprayers are quite small when one considers their surface areas. Materials used in their construction, such as polyethylene for the dominating tank structures, are smooth and displace liquids rapidly. Structures such as suction hoses - with their ribbed profiles - and horizontal metal work tend to retain more than the smooth pressure pipes or vertical members. Nonetheless, the small total volume is rapidly removed with the hose and would be adequate for normal spills. However, more time may be needed if the whole machine was saturated.

Build-up rates on external surfaces from field spraying are dependent on factors such as spray quality and wind. Those conditions we associate as being worst for spray drift and operator exposure are the same for this threat too. Thus smaller drop sizes and, we believe, higher wind speeds will both interact to produce higher external deposits than the converse. Long term build up under "worse fit" conditions are likely to be both rapid and appreciable. Hence, contaminated, parked sprayers, whose residues are then removed by rain to contaminate the soil below, are likely to lead to local doses that far exceed that Approved for normal use.

We believe that field decontamination can be effective but is likely to be more effective when regularly practiced and when starting - as in this study - with clean surfaces. The environmental risk posed by draining the sump in the field, contributes little to the final outcome of the three rinse routine and this bad practice can be avoided.

Internal residues in modern sprayers are dominated by that retained in the pump, the pipework that supplies controls and induction bowls. Using the same pump for spraying, will, therefore, lead to some contamination of the flushing water being applied through the hose. However, correctly used after two previous internal rinses, recontamination levels are low and may produce deposits equivalent to that built up after just a few minutes field use. The good practice of regularly taking a further 3 minutes to externally wash sprayers as part of the full decontamination routine should be encouraged.

PESTICIDE INJECTION METERING

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ABSTRACT

Injection metering systems have a major advantage in relation to pesticide waste in that the main tank of the sprayer contains only water and therefore the requirements for decontamination and disposal of dilute pesticide are substantially reduced. This paper examines the characteristics of some existing systems.

PESTICIDE INJECTION METERING

Injection metering has been available for many years; the systems that have survived the test of time are those with independently powered pumps usually electrically driven. The pumps are usually piston or peristaltic which dictates where the pesticide is injected either before or after the main sprayer pump. Both systems have benefits relating to their mode of operation.

The concept of injection is very similar in both cases and can be utilised for both manual and computer controlled systems using GPS mapping techniques.

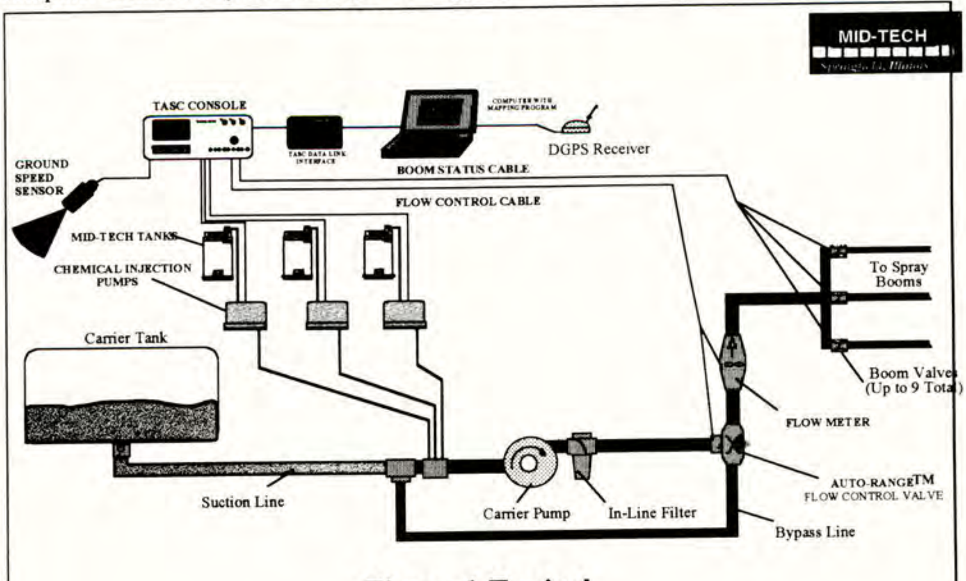

Figure 1 Typical Injection Control System

The main sprayer tank contains the carrier normally clean water which instantly removes one of the main problems of spraying - the disposal of tank washings. In some cases this can amount to filling the tank and spraying it out twice which is very time consuming.

By metering the pesticide into the line while spraying means no mixture remains at the end of the job regardless of whether the field size is know or not. Simply switching off the metering pumps allows clean water to purge the lines of pesticides. For cleaning purposes, one of the main advantages of peristaltic metering pumps is their ability to be reversed enabling the concentrated pesticide to be returned to its container, then by connecting to clean water or washing solution then running the pump will complete the wash out.

Filling the main tank is speeded up as the problem of frothing does not exist allowing high capacity pumps to be used with any accidental spillage being clean water. Filling the main tank can be undertaken at any convenient time rather than having to empty the tank each time and this results in time saving and unnecessary crop damage by having to go through it twice.

With injection it is possible to control the application of individual pesticides by switching on or off or varying the actual rate. This gives the flexibility to adjust the spraying pesticides near watercourses by varying dose or substitution with alternative products. A basic form of spot treatment can be achieved by switching products on and off in different areas of the field.

With the trend of reducing carrier application volumes, the ability to mix exactly what is required for the job is becoming more important. When a sprayer becomes empty and the pressure begins to fall there could be approximately 25 litres remaining in the system. At the traditional rate of 200 litres/ha this represented 1/8 hectare and at 75 litres/ha this increases to 1/3 hectare consequently the expense of the waste is greater.

With new metering systems coming to the market for the dry flowable products give the opportunity to reduce the package waste but still integrate into metering systems.

The issue of closed transfer returnable containers is now being addressed with the ultimate object to carry the container on the sprayer coupled directly to the metering pump. In the early stages it is envisaged that some of the returnable containers will be emptied into holding tanks on the sprayer because their volume is to small to be practical. The use of IPU is an example where 4 - 5 litres/ha are required then it would be necessary to have 4 - 5 containers on the sprayer.

As variable rate applications using computer-generated maps becomes more common, then the only way to apply pesticides will be using injection metering systems. In many respects this could be the easiest way to use GPS initially to record accurately what pesticides were applied where and at what dose rate. Initially with GPS in a controlling mode, the broad-brush approach could be adopted with known areas of a field being selectively treated and at the same time accurately recording what was done. Then over successive years the application map can be refined to give more precise spot treatments.

CONCLUSIONS

Pesticide injection metering is a viable alternative to the standard sprayer taking into account the efficient use of pesticides and the environmental issues particularly in relation to the disposal of wastes. As application technology improves it will become essential to achieve the precision required.