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Internal and External Contamination of Sprayers: Causes and Strategies to Minimise Negative Effects on the Environment

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At the end of every pesticide application the sprayer results contaminated either internally – in the tank and in the hydraulic circuit - or on its external surfaces with a fraction of spray mixture applied in the field. If not adequately managed, these chemical residues may cause negative effects on the environment.
The amount of spray mixture residue in the tank at the end of treatment depends partly on the technical features of the sprayer (fraction not suckable by the pump) and partly on how the sprayer has been adjusted in order to use up the whole pesticide tank content on the sprayed area. Quantity and pesticide concentration of the leftovers are also influenced by the tank capacity and shape as well as by the efficiency of the agitation system. In order to minimise the amount of residues present in the internal parts of the sprayer at the end of the application it is always recommendable to use ENAMA/ENTAM certified sprayers, which fulfil the technical requirements of the International Standards in terms of maximum residuals and efficiency of the tank agitation system. Moreover, when the tank content is going to be finished, it is important to close the backflow line, so to allow the pump to suck as much as possible all the spray mixture present in the sprayer.
Concerning external contamination of sprayers, its amount depends on the sprayers features (e.g. the presence of a fan enhances a lot the external contamination of the machine), on the spray quality (higher contamination applying fine droplets), on the air flow parameters adopted and on the characteristics of the product sprayed (some formulations are more sticky and persistent on the machine).
Management of sprayer cleaning directly in the field allows to simplify the disposal of the effluents at the farm, reducing their amount and concentration. It is therefore necessary to use the rinse water tanks of adequate capacity equipped with efficient systems for internal and external cleaning.

Introduction

At the end of every Plant Protection Products (PPP) spray application, the mixture residues still present in the sprayer tank and in the hydraulic circuit as well as the spray deposits cumulated on the external surfaces of the application equipment have to be correctly managed in order to prevent environmental contamination. Typically, the sprayer cleaning operations are carried out always in the same area in the farm courtyard (Figure 1) using spray lances or high pressure cleaners and employing not negligible volumes of clean water. According to a survey carried out by DiSAFA in 2010 in 100 Italian vine farms the average volume of water used to clean one sprayer amounts to 120 Litres (60 L used for the internal cleaning and 60 L used for the external cleaning of the equipment). If the farmyard is not provided with a concrete platform having a system for collecting PPP contaminated waste water, the risk of originating PPP point sources is pretty high. Prevention of high level of spray mixture residues at the end of the application and use of the devices enabling to manage most of sprayer cleaning operations in the field are useful strategies to simplify the management of the sprayer at the farm after the treatment and to prevent risks of environmental contamination.

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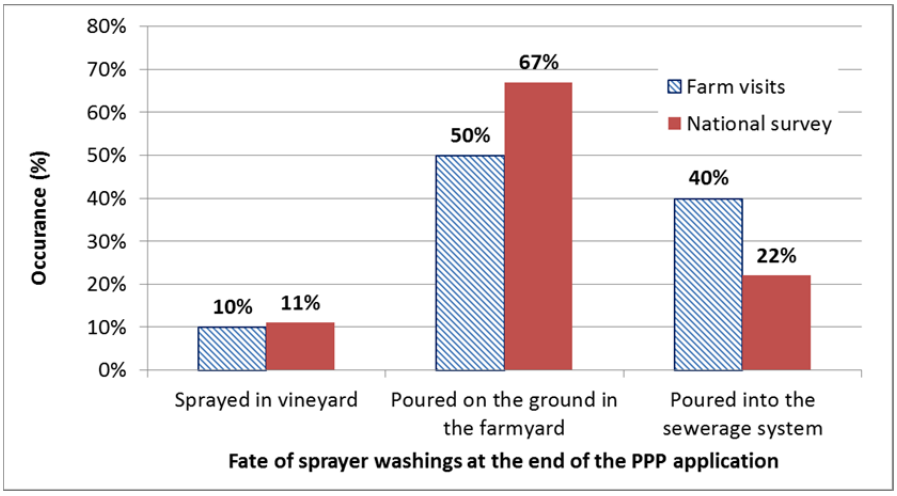

Figure 1: Fate of sprayer washings at the end of the PPP application in Italian vine farms (DiSAFA survey, 2010).

Internal contamination of sprayers

According to a survey carried out in 2010 by DiSAFA – University of Turin in 100 vine farms in Piemonte region (North-Western Italy) the average total amount of mixture residue in the sprayer tank at the end of the application amounts to 24 liters, but in several cases values over 50 liters were registered.
These not negligible amounts of spray mixture residue still present in the sprayer tank at the end of treatments are composed by two fractions: a) the volume of spray mixture that is not suckable by the pump and b) the volume of spray mixture exceeding the effective volume sprayed on the crop surface (Figure 2).

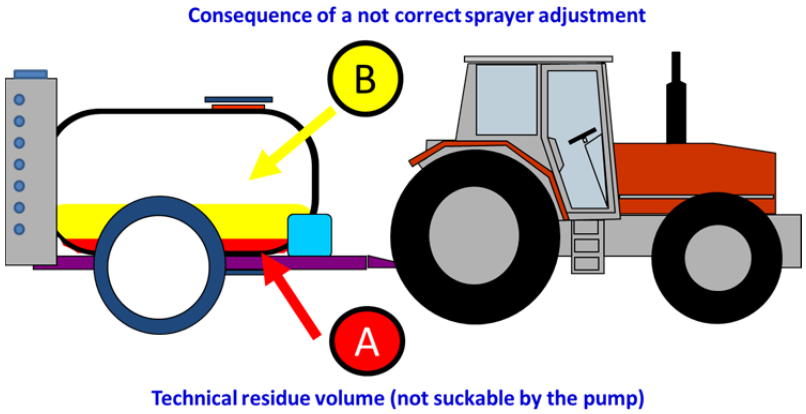

Figure 2: Repartition of spray mixture residue still present in the tank at the end of the spray application.

Concerning the first fraction, it depends on the constructive features of the sprayer, in particular the shape of the tank bottom and the position of the pump sucking hose in the tank. In order to minimise this residue it is recommendable to prefer the use of ENAMA/ENTAM certified sprayers which comply with the performance limits reported in ISO Standards and therefore are featured by minimal amounts of spray mixture residues technically not suckable by the pump.
Moreover, the presence of a by-pass valve in the sprayer hydraulic circuit, enabling to close the backflow into the tank when the spray mixture is going to be exhausted, allows to reduce at least by 50% the volume of liquid in the tank not sucked by the pump. This is a device that is typically not present in the majority of the sprayers in use but can easily be retrofitted on the spraying equipment.
The second fraction is a consequence of a not precise assessment of the exact amount of spray mixture to introduce in the sprayer tank, which is related on one hand to the adjustment of the sprayer and on the other

hand to the constructive features of the machines. The correct volume to introduce in the tank, in fact, has to be determined on the basis of the effective sprayed volume and of the crop surface to apply. The effective sprayed volume has to be verified measuring the total flow rate of the sprayer, the effective forward speed in the field and the inter-row or nozzles distance. To apply a determined crop surface, once the exact amount of spray mixture to introduce in the sprayer tank is defined, however, it often happens that due to the poor precision of the tank content indicators that are usually mounted on the sprayers tanks, considerable errors can be made in tank filling. To overcome this problem, the use of a programmable flow meter can help in determining more precisely the volume of water inserted in the machine and therefore to prevent high amounts of leftovers, as the employment of an ENAMA/ENTAM certified sprayer for which the precision of the tank indicator has been checked by a third part laboratory.

External contamination of sprayers

The amount of spray mixture applied which deposits on the external surfaces of the spraying equipment depends on the sprayer type, the operating parameters and the environmental conditions, and is also affected by the agrochemicals formulations. Concerning air-assisted and pneumatic sprayers used in arboreal crops, the part of the machine which typically results more contaminated is the rear one including the fan. Especially the conventional axial fan air-assisted sprayers are featured by higher deposits on and around the fan due to the suction position of the latter, which conveys a not negligible fraction of the sprayed droplets on the fan blades and on the fan case (Figure 3). From this perspective the machines equipped with a fan sucking air from the front part of the sprayer, away from the nozzles positions, rather than from the rear part of the sprayers where the nozzles are installed, can contribute in minimising external contamination of the sprayer. Moreover, the adoption of reduced fan speed and therefore of a lower air flow rate contributes to contain the external contamination of the sprayer, as in this case less droplets sprayed from the nozzles can be sucked from the fan.
Also a high roughness of the sprayer tank can contribute to retain spray deposits on the external surfaces of the machine; the use of an ENAMA/ENTAM certified sprayer, complying with the ISO requirements about the roughness of the external surfaces of the tank (Rz ≤ 100 µm), is recommendable in order to prevent this phenomenon.

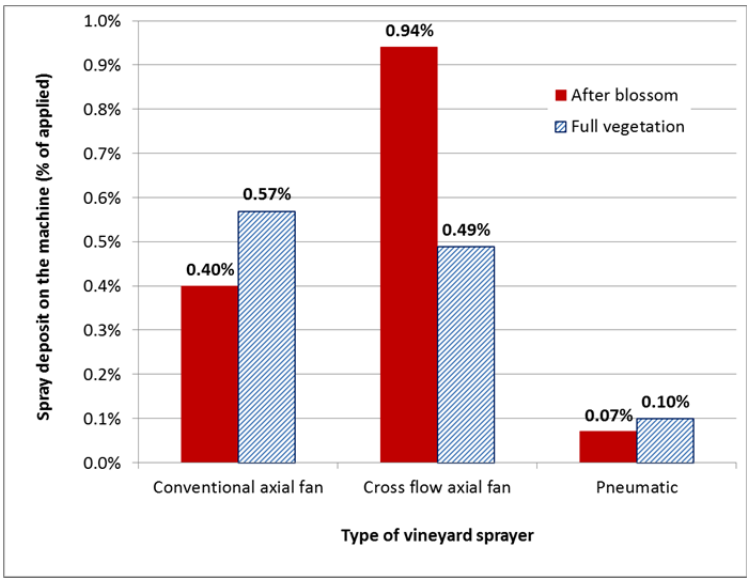

Figure 3: Spray deposits on the external parts of the sprayers measured in vineyards using different machines and operating at two growth vine stages. Experiments were made by DiSAFA applying a test solution of water and yellow dye E102 Tartrazine.

The spray quality is an operating parameter which has an influence also on the external contamination of the equipment. Typically, the use of coarser droplets, as those produced by air induction nozzles, enables to drastically reduce the external contamination of the sprayer (Figure 4).

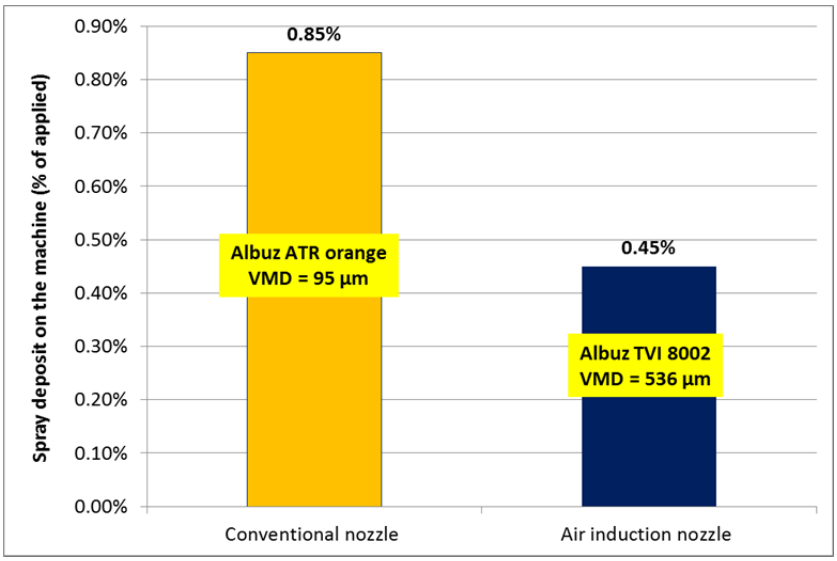

Figure 4: Spray deposits on the external parts of the sprayers measured in vineyards using different nozzle types and droplet sizes, operating at 1.0 MPa pressure and using a cross flow axial fan. Experiments were made by DiSAFA applying a test solution of water and yellow dye E102 Tartrazine.

The environmental conditions influence the amount of spray deposits on the application equipment: when air temperature increases and relative humidity decreases the evaporation of finer droplets results higher and therefore the external sprayer contamination is less. Last but not least, the type and formulation of the PPP and the number of applications made using the same product during the season play a role on the amount of spray deposits on the external surfaces of the sprayer (Balsari et al., 2016). In Figure 5 the amount of a.i. in washings from external cleaning of a vineyard pneumatic sprayer after five different applications made during the season are reported. Each cleaning was carried out employing a high pressure cleaner (3.0 MPa) using about 50 litres of clean water.

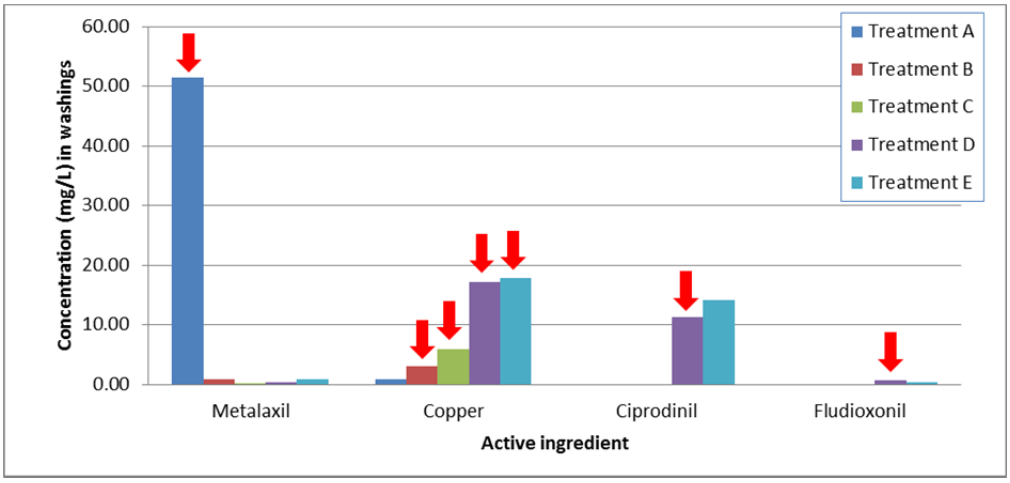

Figure 5: Concentrations of a.i. detected in the washings from external cleaning of a vineyard pneumatic sprayer after each treatment. The red arrows indicate treatments where the specific a.i. was applied (DiSAFA tests 2016).

Management of sprayer internal and external cleaning in the field

In order to minimise the risks of environmental contamination related to the internal and external cleaning of the sprayer, due to point sources originated at the farm, it is recommendable to make these operations directly in the field, using the rinse water tank and the sprayer cleaning devices attached to the machine. Since the entry into force of the amended Machinery Directive (127/2009/EC), the presence of a rinse water tank, having

a capacity of at least 10% of the nominal volume of the main tank, is mandatory for all sprayers, except than for the mounted air-assisted sprayers having a main tank with a capacity below 400 litres. Nevertheless, even on the old sprayers not originally equipped with a rinse water tank, it is possible to retrofit it, providing a three-way valve enabling the sprayer pump to suck alternatively from the main tank of from the rinse water tank. The rinse water tank shall feed either systems for internal tank cleaning, that are typically rotating nozzles positioned inside the main tank, or devices for the sprayer external cleaning, as lances that can be attached to the machine. In order to maximise the efficiency of the use of the clean water contained in the rinse water tank it is however fundamental that the hydraulic circuit of the sprayer is equipped with a second three-way valve enabling to close the backflow line in the main tank. Thanks to this valve, in fact, it is possible to make circulating the whole pump flow rate on the pump itself and therefore to separately rinse the sprayer main tank and the hydraulic circuit and to save some clean water for carrying out the external cleaning of the machine (Figure 6).

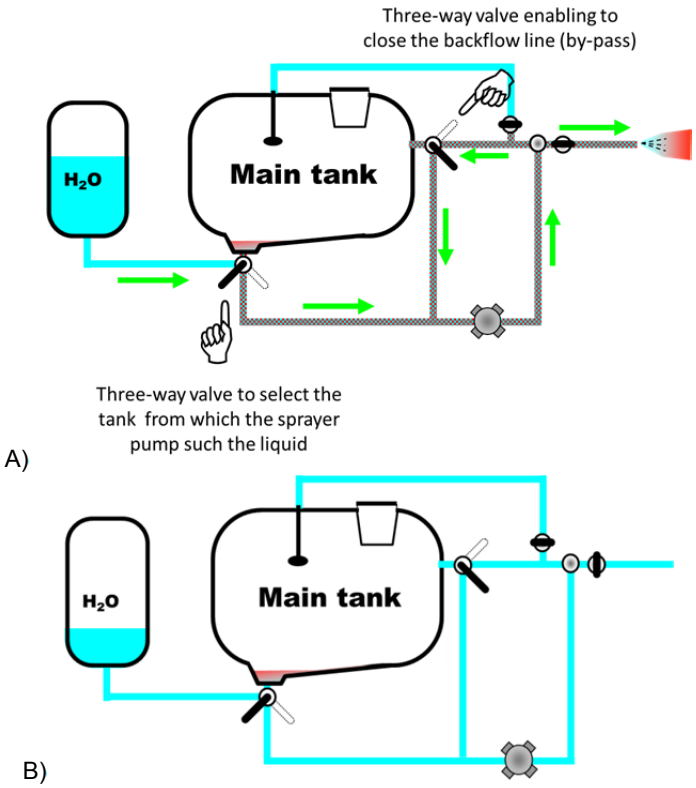

Figure 6: Example of hydraulic circuit of a sprayer equipped with a by-pass valve enabling to close the backflow line: A) when the pump sucks clean water from the clean water tank and feeds the boom nozzles, the valve on the back flow line (by pass valve) remains closed and the liquid recirculates directly on the pump; this allows the complete rinsing of the hydraulic circuit. B) After completing internal sprayer cleaning, some clean water shall be still available in the clean water tank to make the sprayer external cleaning using a device (e.g. spray lance) connected to the clean water tank.

Efficiency of the internal tank cleaning systems is conditioned by the efficiency of the agitation system in the tank as the poorer is the agitation efficiency, the higher is the amount of residues present in the tank to be removed (Figure 7). Nevertheless, the internal tank cleaning systems installed on ENTAM certified sprayers and tested according to ISO 22368-3 test method resulted always able to achieve a cleaning efficiency of more than 80% (Tamagnone et al., 2016). Also, the subdivision of the sprayer internal cleaning in more separate steps is useful to get a higher cleaning efficiency. The diluted spray mixture obtained from the internal cleaning of the sprayer can be applied directly on the crop, so that when returning at the farm, the sprayer will contain just a limited residue of diluted spray mixture, that in most cases could be left in the sprayer until next filling.

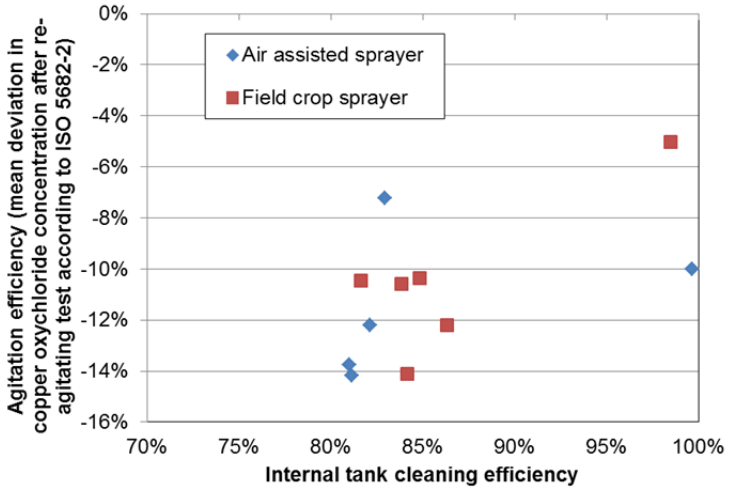

Figure 7: Comparison between efficiency of internal tank cleaning systems measured according to ISO 22368-3 and efficiency of the tank agitation system measured according to ISO 5682-2 in some ENTAM certified sprayers.

Concerning the external cleaning of the sprayer, to carry out it in the field immediately after the treatment, when the spray deposits on the machine are still relatively fresh, allows to easier remove these deposits even with spray lances operated at low pressure and employing a reduced amount of water. A reported also in TOPPS BMPs (www.topps-life.org), the external cleaning in the field shall be carried out in an area of the field away from water bodies, avoiding to repeat the operation always in the same place at each treatment.

Conclusions

The amount of spray mixture residues still present in the sprayer at the end of the application depends on technical features of the machine and on the correct adjustment of the spray volume introduced in the tank to apply the intended crop surface. The use of some devices (e.g. three-way valve to close the backflow line, programmable flow meter to insert in the tank the exact volume of water needed) can help in minimising these residues. Also the amount of spray deposits on the external surfaces of the spraying machine is influenced by some technical characteristics of the sprayers (e.g. tank surface roughness, position of the fan air suction section in air-assisted sprayers) an by some operating parameters (e.g. droplet size and air flow rate), but it's also conditioned by environmental conditions and PPP formulation characteristics.
Use of rinse water tank and of the cleaning devices attached to the sprayer for making the internal and the external cleaning of the sprayer directly in the field just at the end of the application is recommendable because it allows to prevent risks of generating point sources in the farmyard, simplifying the disposal of the effluents at the farm, especially reducing their amount and concentration. To operate this way it is necessary that the machines are equipped with adequate rinse water tanks and cleaning devices and that the operators are trained to correctly use them following also the specific TOPPS BMPs. The more complex and costly alternative is to carry out the sprayer cleaning operations in the farm on cleaning areas equipped for collecting the PPP contaminated waste water and to foresee adequate systems for their treatment at the farm or for their delivery at specialised companies for disposal of dangerous wastes.

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TOPPS website: www.topps-life.org