TOPPS

EOS – HANDBOOK

Environmentally Optimized Sprayer

Background

and

Documentation

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Foreword

ECPA represents the Crop Protection Industry in Europe, and has supported the EOS – project (Environmentally Optimised Sprayer) as a part of the wider stewardship activities it sponsors.

Plant Protection Products (PPP) are applied to protect crops from damage caused by weeds, diseases and pests. Due to strict legislation in the EU many PPPs have been removed from the market, but despite the safety of remaining products, as with most human activities, the use of PPPs can have some secondary effects, for example traces of PPPs may reach water.

ECPA stewardship activities are therefore targeted at sustainable use of PPPs.

An EU - LIFE programme co-funded project known as TOPPS, ran from 2005-2008 and developed recommendations for Best Management Practices (BMPs) together with partners in 15 countries aimed at mitigating the losses of PPPs to water from point sources.

A key learning from TOPPS was that apart from the mitigation, concepts need to include the adviser and farmer, the application techniques and the infrastructure as key aspects in any risk reduction approaches. Successful risk reduction concepts therefore need to address the whole crop protection process.

A process-wide view is often difficult to achieve in practice, as experts often tend to adopt a fairly narrow specialist view, which does not address the entire process, or its complexities.

In the EOS project we sought to bring experts together from different areas, focussing on the interface between application techniques and chemical crop protection development: i.e. covering application techniques, farmer advice, and crop protection industry. Sharing knowledge from different areas and understanding each other’s challenges is essential to finding the best best possible overall solutions.

Now it is necessary to communicate the results of the project, and seek buy-in from players and stakeholders who may not have been directly involved in the EOS project discussions. I would like to thank all partners involved in the project for their work and wish all success to the ongoing dissemination activities. We hope that the EOS project will fulfil one part of the overall picture which is needed in order to ensure a more sustainable use of PPPs.

Dr. Friedhelm Schmider

Director General ECPA

Content

1. EOS – Project (Environmentally Optimized Sprayer)

1.1 Introduction

Plant Protection Products (PPP) containing pesticides (active ingredients) are applied to protect crops from weeds, diseases and pests. Their application can lead to unintended losses of pesticides to surface water basically by two main entry routes.
a) Point sources: Mainly related to the handling of PPP on farm during cleaning, filling, remnant liquid management, transport and storage.
b) Diffuse sources: Mainly related to run-off from field after application, discharge from drainage and off target deposition of spray due to wind (drift) (Figure 1)

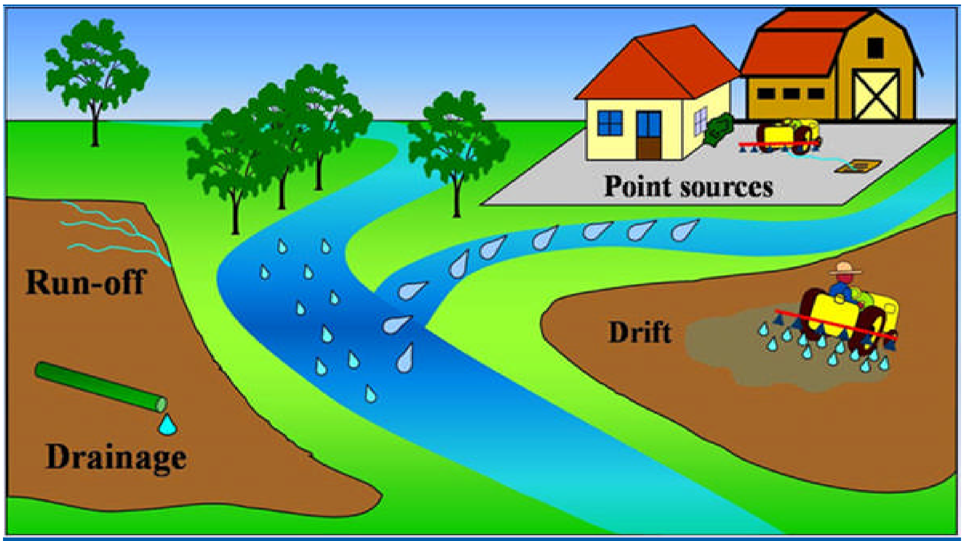

Figure 1: Entry routes of Plant Protection Products (PPP) into surface water

The European project TOPPS* and the follow up project Bridge supported by ECPA**, defined common and harmonised Best Management Practices (BMPs) in 17 EU countries in order to avoid PPP losses to surface water from point sources. BMPs were developed by working through three key perspectives and the relevant working processes (Figure 2)

1.2 Lessons learned from TOPPS

- Risk awareness for surface water pollution is not very well developed at the level of operators or stakeholders (TOPPS surveys)
- Regulatory requirements and mitigation measures primarily concentrate on the application of Plant Protection Products(PPP) but the whole process (from storage to post application activities) is not sufficiently in focus (Infrastructure, Technology, Disposal)
- Efficient risk mitigation needs to be organised along the crop protection processes addressing the correct behaviour of operators and the relevant technical and infrastructural risk mitigation measures.

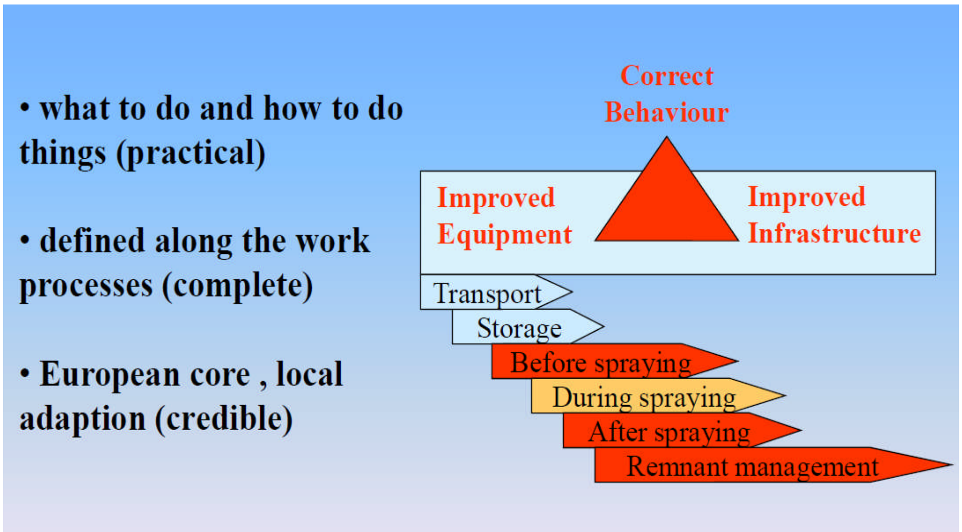

Figure 2: Key perspectives and processes in the development of Best Management Practices (BMPs)

- Communication between Crop protection industry and Sprayer manufacturers should be improved to better understand each other's needs and challenges. (Crop protection industry with few R&D companies – Sprayer manufacturers > than 1000 companies in EU)
- Improvements in the use of modern spray equipment, if made solely through new purchases, is a long term process. In TOPPS surveys the average age of sprayers was 12 years. Better advice is needed to enable the right decisions and choices sooner.
- Pollution from point sources can be largely avoided by creating the necessary awareness and support at all levels. Water protection is a multi stakeholder task and cannot be managed independently.

1.3 Legal Context

Agriculture is considered a major polluter of water. Main pollutants are nutrients (Nitrogen and Phosphates) but pesticides can also be found in some catchments. It is therefore necessary to create the awareness with both operators and stakeholders on existing or further developments in effective mitigation. Such measures have the potential to largely help avoid the pollution of water. Legal initiatives on registration and use which are currently in the development and implementation phase address water protection, environmental issues and risk mitigation measures (Figure 3)

a) WFD (Water Framework Directive)

Member states are requested to implement the WFD to reach good status of waters by 2015. Elements of the implementation strategies are:
- Programs of Measures (POM) which countries are required to establish for each river basin district.
- River Basin Management Plans RBMP which will provide a framework of actions at Member state level.
- Strategies to avoid pollution of water by "priority substances" as identified at EU level and compliance with Environmental Quality Standards EQS

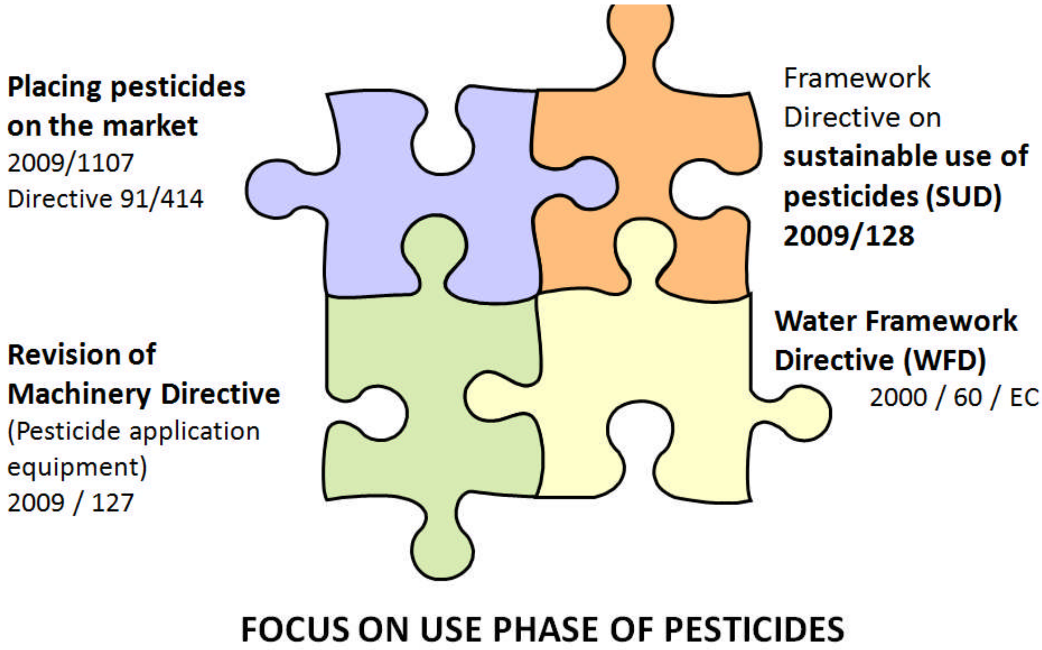

Figure 3: European legal initiatives to be implemented by national authorities

b) The Framework Directive on the Sustainable Use of Pesticides (SUD)

The Directive seeks to achieve more sustainable use of pesticides as well as a significant reduction in risks, consistent with the necessary level of protection against pests. It is focussed on the use phase of plant protection products.

Key aspects are:

- National Action Plans (NAPs) to reduce risks and dependence on pesticides, which Member States are required to establish. Stakeholders will be involved in the establishment and implementation of NAPs
- Creation of appropriate trainings and certification systems for professional users, distributors and advisers
- Regular and compulsory inspection of application equipment
- Specific measures to enhance protection of the aquatic environment: notably creation of buffer zones where there can be no application or storage
- Reduction of pesticides in sensitive areas, such as special conservation areas.
- Handling and storage of packaging and remnants of pesticides
- The promotion by Member States of Integrated Pest Management (IPM) schemes

There is a clear link between the practical measures related to training and education regarding the sustainable use of pesticides which the SUD seeks to promote at Member State level, and the agriculture-related elements of the WFD Programmes of Measures that the Member States are obliged to prepare.
The EOS project was developed on the learning's from the TOPPS project* and aims to help in proposing effective and practical measures, creating awareness among operators and stakeholders and to contribute to achieving more consistency as current harmonisation of measures across Member States are very weak.

c) **Machinery Directive**

Some important requirements related to environmental aspects are defined by European and / or International Standards (EN, ISO). These standards are acting more as guidelines and reflect minimum requirements, which should be met (Herbst et al 2002). Only when European harmonised standards are available, it is necessary to follow their requirements in order to comply with the prescriptions of the European Directives.
Currently most of these standards are not harmonised and considered voluntary. This may change after 2011 with the implementation of the new Machinery Directive (EC 2009/127) and with the consequent application of the correspondent European harmonised standard. The "Declaration Procedure" for new sprayers as established in Germany (JKI), where the compliance with the standards was controlled, will terminate at the end of 2011. In future, manufacturers should self-certify their sprayers following the harmonized standards.
The EOS project does not interfere with the Standards. The EOS evaluation compares the sprayer capability on the basis of the best in class technology. Already today we have sprayers which perform 50% better than required by the Standard in some key environmental features (Total Residual Volume - ENTAM). Such information is not yet widely known and we hope EOS will help to provide such information to create more awareness by farmers and advisers for environmentally relevant features.

d) **Placing plant protection products on the market** (Directive 91/414/EEC being /replaced by Regulation)

This is the legislation governing authorisation and placing of plant protection products (PPP) on the market. This legislation is concerned with the evaluation of pesticides to ensure that they can be used safely in the EU from the perspective of the human safety, environment and residues on food. The legislation is essentially concerned with the pre-market testing phase.
At the member State level there are clear links to the use phase of PPP regarding specific restrictions or requirements aimed at mitigating risk to water e.g. by mandating buffer strips between sprayed crops and any water body.

1.4 Objectives of the EOS - project

- **Analyse and evaluate** sprayer's technologies in their capabilities to reduce risks of PPP losses to the environment e.g. by reducing waste generation and off target losses.
- **Create awareness** for the risk mitigation potentials which could be realized by environmentally optimized sprayers (Manufacturers, Advisers, Farmers , Water-managers and Authorities)
- Create a **platform for discussions among all players** along the crop protection process to better understand each other's challenges and support further innovations
- Help to **develop additional sales arguments** for environmentally optimized sprayers to help to compete better in the market.

- Provide **transparent information** to manufacturer, advisers and stakeholders on the « environmental friendliness » of sprayers, by evaluating their contribution to risk reduction to the environment with best in class technologies.

- Develop a basis for water companies, authorities to **justify incentives** for improved sprayers (new or upgraded).

- Reduce off target losses of PPP and make their use **more sustainable**.

*TOPPS was a 3-year, multi-stakeholder project covering 15 European Countries - it stands for **T**rain the **O**perators to prevent **P**ollution from **P**oint **S**ources. The project started 1st November 2005 and ended 30th October 2008. TOPPS was funded under the European Commission's Life program and by ECPA**, the European Crop Protection Association. TOPPS aimed at identifying Best Management Practices and disseminating them through advice, training and demonstrations at a larger co-ordinated scale in Europe with the intention of reducing losses of plant protection products to water. After TOPPS the dissemination activities were further supported in the 15 TOPPS countries by ECPA through the Bridge project. Additionally the development of the Best Management Practises (BMPs) was expanded to Romania and Bulgaria (see further information on www.TOPPS-life.org)

1.5 Execution of the EOS – project

The EOS – project concentrated only on areas where sprayer technologies for field crop sprayers and orchard sprayers can contribute to environmental risk reduction. Technologies are seen as important enablers in risk mitigation concepts. Most important in any risk mitigation approach is the operator.
Technologies evaluated in EOS are available in the market and have passed the experimental stage. Evaluations were done by a team of international experts. They contributed their knowledge and competences covering aspects from science, practical farmer's advice, Crop Protection Industry and Sprayer Manufacturers. Four group meetings and various teleconferences were conducted. EOS started in January 2010 and was finished end of February 2011.
The project work was strongly supported by a technical support group, which made the necessary preparations and consolidation (DEIAFA- University Torino, Italy; Julius Kühn Institut (JKI), Braunschweig, Germany and the Institute of Pomology&Floriculture, Skierniewice, Poland).
The Web based evaluation tool was realized together with Creanetsoft, Gräfenroda, Germany.

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2. Sources of PPP losses to water

The importance of different entry routes of PPP to water can only be estimated as the variability in practice can be very high. It is also difficult to separate the different entry routes in research projects. Nevertheless it is possible and worthwhile to make estimates based on available research to direct focus to the most important aspects (Figure 4).

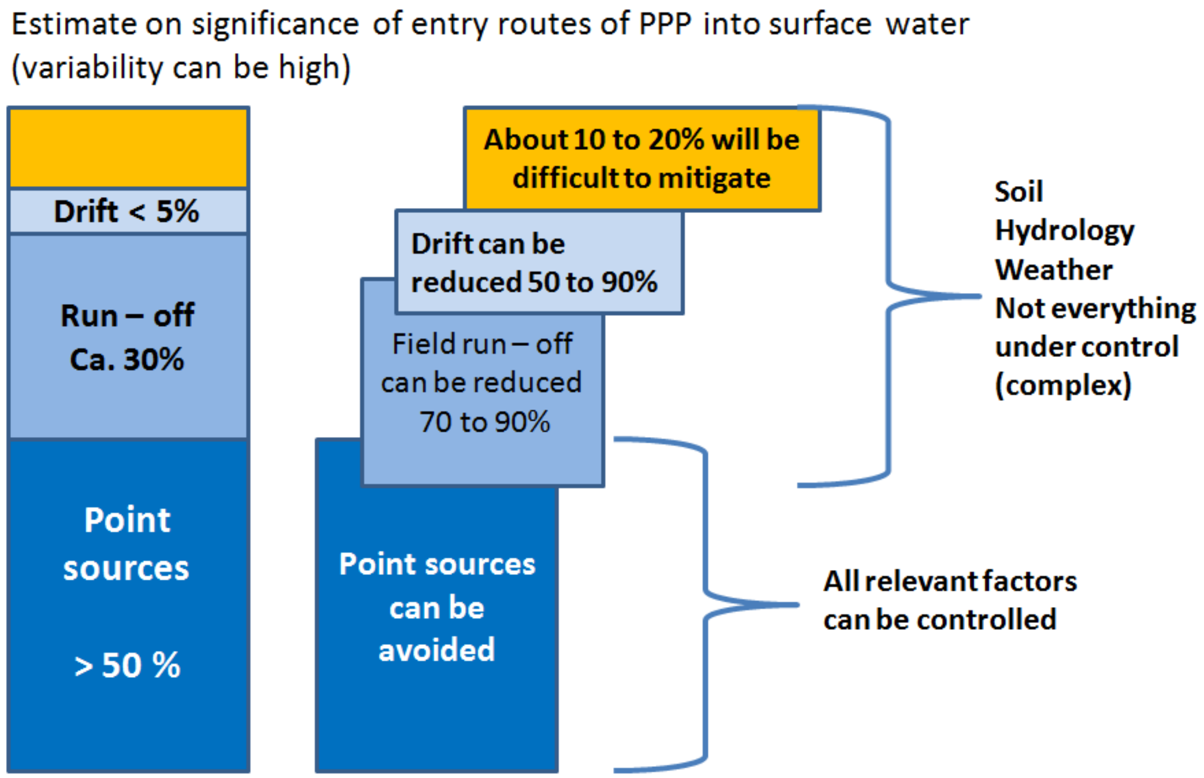


Figure 4: Estimated significance of different entry routes of PPP into surface water

Long-term research projects since 1992 in Sweden suggest that Best Management Practices combined with improvements in equipment and infrastructure can mitigate about 90% of PPP entries into surface water (Vemmenhoeg catchment: J.Kreuger, Swedish Univ.Agric. Sciences)

2.1 Point sources

Intensive studies in Germany, Belgium and the UK show that point sources are the major entry route of PPP into surface water. The TOPPS project concluded that this entry route contributes more than 50%.
Studies from University of Giessen, Germany in 5 catchments showed that point sources contributed 65 to 95% (Figure5, 6), studies in Belgium measured 70% from point sources. In the UK about 40% for point sources was measured even when the operator was made aware that measurements were taken (Cherwell).
Stakeholder surveys during the TOPPS project showed across EU member states a high consensus (80%) that mitigation of point sources are the easiest way to reduce PPP losses to water. Therefore a specific focus on point source mitigation measures can support fast wins for water protection.

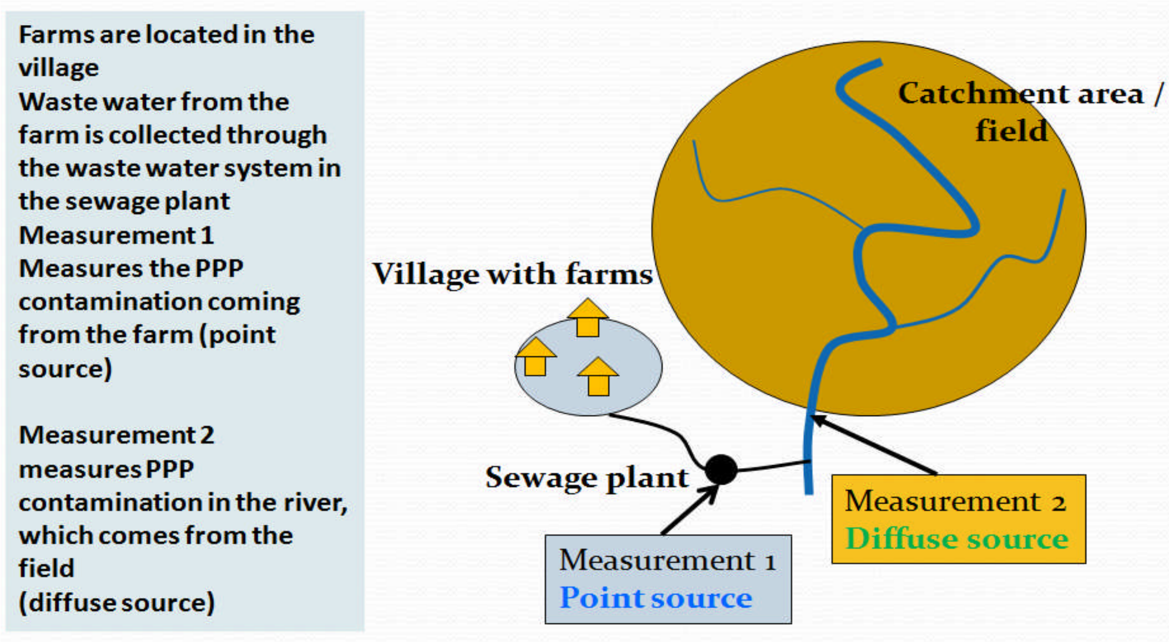


Figure 5: Study method to investigate point source and diffuse source entries into surface water. Frede et al Univ. Giessen ,TOPPS Forum Germany Oct 2006 (changed)

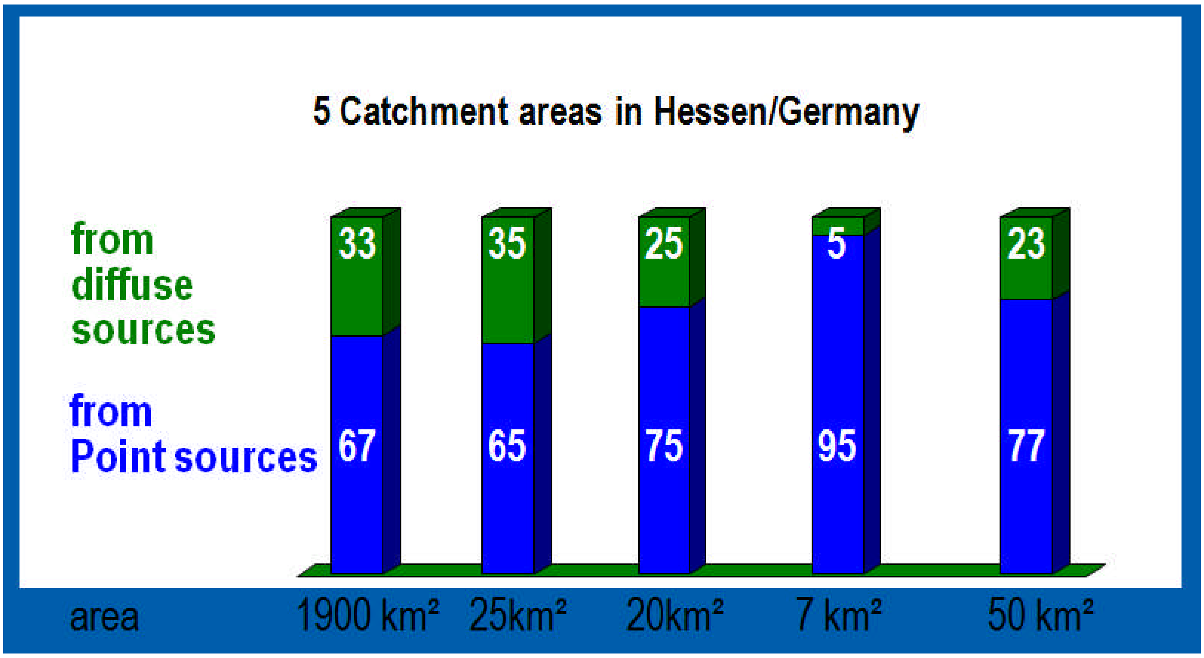


Figure 6: Point and diffuse source measurements in surface water for 5 different catchments Frede et al Univ. Giessen, TOPPS Forum Germany Oct 2006 (changed)

The TOPPS project identified the three most important risk areas for point sources in order of importance. This was supported by responses received from stakeholder and farmer surveys.

- Cleaning processes (sprayers and other equipment / tools)
- Filling process

- Remnant management process (management / treatment of contaminated liquids from washing, maintenance etc.)

The predominant significance of the cleaning of sprayers is highlighted in research results presented by Frede 2006 (University Giessen; TOPPS German National Forum) where in 5 catchment areas reductions in the level of water pollution between 61 and 82% could be demonstrated by just transferring sprayer cleaning from the farmyard to the field.(Figure 7)

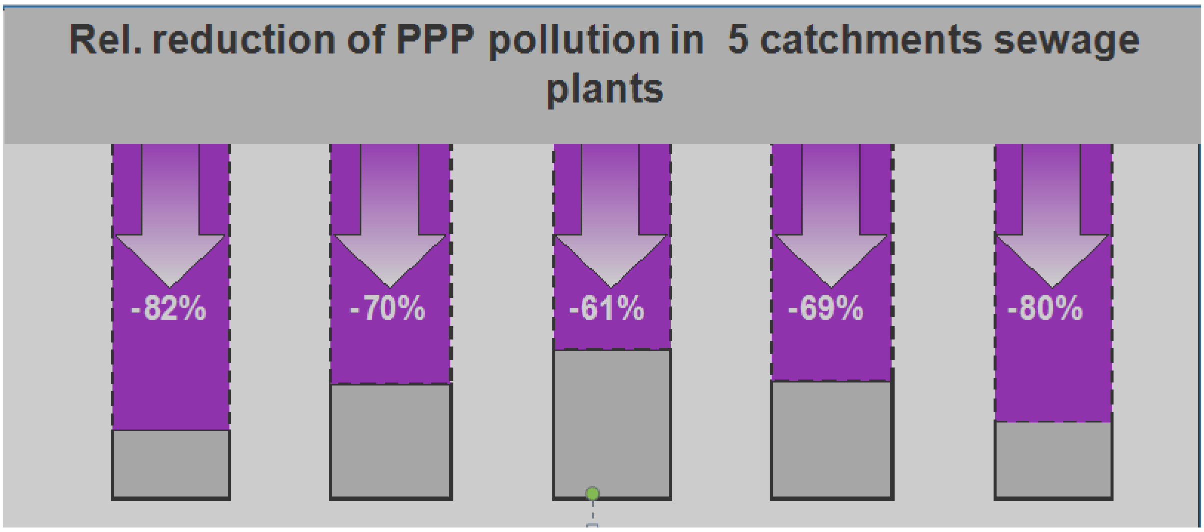


Figure 7: Reduction of point source contamination if cleaning of sprayer was transferred from farmyard to the field. Frede et al Univ. Giessen, TOPPS Forum Germany Oct 2006

2.2 Diffuse sources

Contrary to point sources, diffuse sources mitigation measures are specific to a catchment or a field. Mitigation concepts addressing diffuse sources are complex and need to consider soil, hydrologic, climatic conditions and general cropping practices. General recommendations are therefore difficult to give and if mitigation measures are not addressing the specific aspects in a transparent way it is unlikely that they can be broadly accepted.

Key risks are

- Run off from the field
- Discharge from drained fields
- Drift

The diffuse source risk aspects are not further described, because except for drift mitigation, sprayer technology cannot contribute much to the risk mitigation.

3. Areas where sprayer technology can contribute to reduce the risk of water contamination

Based on TOPPS results, the EOS project team analyzed entry routes of PPP into water and estimated where sprayer technologies offer significant contributions to risk mitigation. As pointed out key factor in the mitigation of water pollution is the correct behaviour of the operator. The best sprayer will not help if it is not used and maintained correctly. Equipment as well as infrastructure therefore needs to be seen as key enablers in mitigation concepts. They can help to reduce the risks through respective designs and technical features which help to reduce the problem from the beginning (e.g. lowest residual volumes) and to avoid mistakes (e.g. tank full alarm). Sprayer developments as well as the sprayer testing schemes are focused strongly on the precision of the application (dose control, exact distribution etc.) and various productivity parameters (speed). The EOS project intends to bring the environmental aspects more strongly in focus and to create further awareness among stakeholders for these aspects. (Figure 8)

Sources of surface water contamination	Risk evaluation	Sprayer mitigation potential
POINT SOURCES		
CLEANING	+++	+++
FILLING	++	++
REMNANT MANAGEMENT	++	++
STORAGE	+	-
TRANSPORT	+	++(+)
DIFFUSE SOURCE		
RUN OFF	+++	-
DRAINAGE	+(+)	-
DRIFT	+ (+)	++(+)

+++ strong, + weak, - no mitigation potential

Figure 8: Evaluation of sprayer mitigation potentials to reduce the risk of water contamination

4. EOS risk areas

Based on the analysis of the main emission routes of PPP to water and the potential of sprayers to contribute to the risk mitigation, key EOS risk areas were defined and weighted on their significance (Figure 9) (see also Roettele et all 2010, 2010²)
These EOS risk areas were further evaluated for Field crop sprayers and Orchard sprayers.

a) Inside contamination
The aspect of the inside contamination of sprayers was given the highest weight. Technical solutions which reduce inside contamination and allow good cleaning results in the field

have the biggest potential for the risk mitigation. This is higher in Field crop sprayers (45%) compared with Orchard sprayers (35%). It was also considered that the frequency of cleanings for Field crop sprayers is higher (seasonal crops, rotations, different crop types; more frequent PPP changes)

b) Filling
Next critical aspect was the filling of sprayers with concentrated product and water. Between the sprayer types no differentiation was made (weight 20%)

c) Remnant Management
This aspect considers how easy contaminated liquids can be managed through technical solutions and how remnants can be reduced to a minimum by respective technical designs. Field crop sprayers were rated higher (15%) because the remnant management is more complex and volumes higher than compared with orchard sprayers, mainly due to longer booms and pipes.

d) Outside contamination
Especially for air assisted sprayers deposits on the outside of the sprayer can be significant. Technical solutions to reduce the amount of deposits (surface design, deflector structures or shielding, other innovations) as well as attached devices to enable cleaning in the field can help to reduce risks. This aspect was rated higher for Orchard sprayers (20%) compared with Field crop sprayers (10%)

e) Drift and Spray losses
Drift and spray losses have been weighted 10% for Field crop sprayers and 15% for Orchard sprayers.

In the following chapters the EOS risk areas are further described.(4.1 through 4.5)

EOS - risk areas	Field crop sprayer	Orchard sprayer
Inside contamination	**45**	**35**
Outside contamination	**10**	**20**
Filling	**20**	**20**
Remnant Management	**15**	**10**
Drift + spray losses	**10**	**15**
Total	**100**	**100**

Figure 9: Weighting factors of the different EOS risk areas used in the EOS evaluation model for Field crop - and Orchard sprayers.

4.1 Inside contamination

Due to technical limitations residual volumes remain in the sprayer even when spray activity is exhausted and only air is arriving at the nozzles. The correct management practice of these residual volumes has a big impact on losses of PPP to surface water.
TOPPS surveys have shown that the awareness on residual volumes in sprayers is not very well developed. Also information materials from sprayer manufacturers are often not addressing these issues sufficiently (Figure 10).

The following definitions of residual volumes need to be considered (EN Standard 12761: Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Field crop sprayers (section 2) and orchard sprayers (section 3)).

a) Total residual volume
   Volume which remains in the sprayer and cannot be delivered at the intended application rate (Indicator: 25% drop of pressure shown at manometer)
   (Examples see table 1,2)

b) Dilutable volume
   Volume which can flow back to the tank

c) Non dilutable volume
   Volume which cannot flow back to the tank. It mainly remains in booms, filters or other devices

d) Left over spray volume
   Volume which results from incorrect calibration of the sprayer. Spray liquid is left over in the tank and is not used up during the application. Technical features can support the correct calibration of sprayers (e.g. precise measurements of water filling)

Remark: Two definitions for "empty sprayers"
a) EN Standard 12671 on Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Field crop sprayers and Orchard sprayers
Total residual volume: Spray mixture which remains in the sprayer, which cannot be delivered with the intended application rate. Indicator: 25% drop of pressure shown at manometer (Focus on application)

b) ISO Standard 22368: (Crop protection equipment -- Test methods for the evaluation of cleaning systems -- Part 3: Internal cleaning of tank)
Total residual volume: Spray the mixture out until there is no longer any further liquid coming out of the nozzles (shut off circulation) Indicator: nozzles blow air (Focus on cleaning)

Between the two definitions differences in total residual volume can be up to 50%.

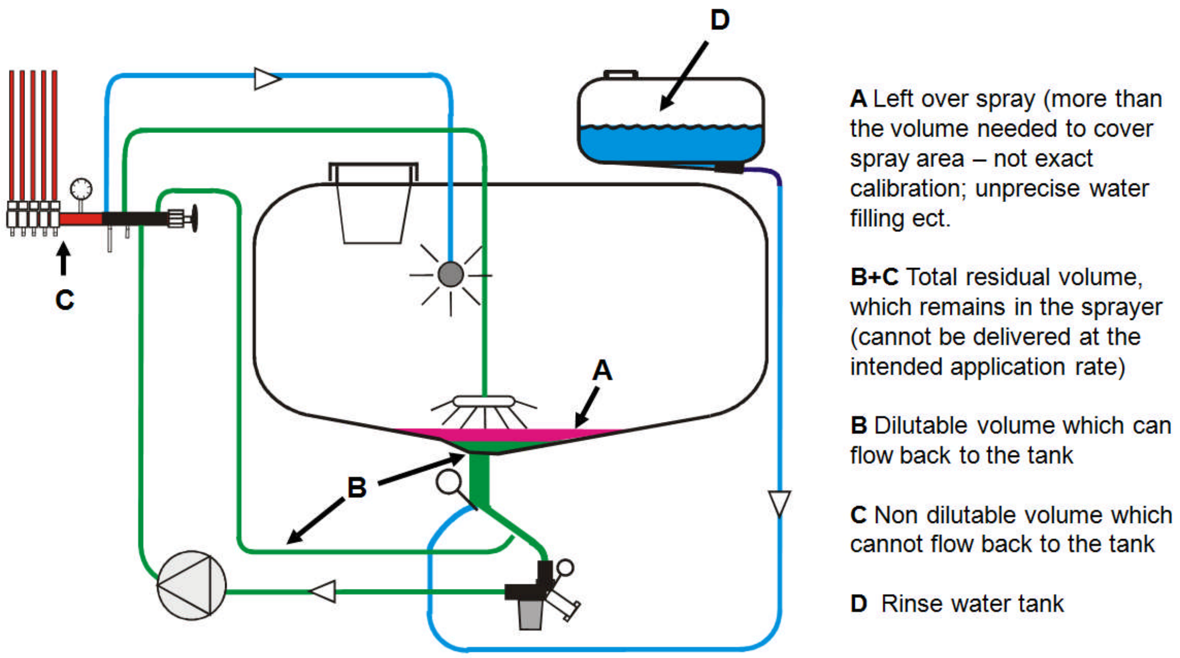


Figure 10: Definition of residual volumes in sprayers

Table 1: Total residual volume for field crop sprayers according to the Standard EN 12761- 2 (Example for different tank volumes and boom lengths

Total residual volume in l (EN 12761-2)				
Tank		Boom		
Tank volume	0, 5 %	length m	2l / m	Total litres
800	4	15	30	34
3000	15	21	42	57
4200	21	36	72	93

Table 2: Total residual volume for orchard sprayers according to the Standard EN 12761(Example for different tank volumes)

Total residual volume in l (EN12761-3)		
Tank volume	%	Total litres
400	4%	16
800	3%	24
1500	2%	30

4% of nominal tank volume for < 400 l tank volume
3% of nominal tank volume for > 400 l to 1000 l tank volume
2% of nominal volume for > 1000 l tank volume

Between field crop sprayers and orchard sprayer the amount of residual volumes is different mainly because of the longer booms and pipes.

Sprayer tests conducted by ENTAM (European Network Testing Agricultural Machinery) referring to the residual volumes show that all sprayers tested comply with the standard EN 12761 (Figure 11)

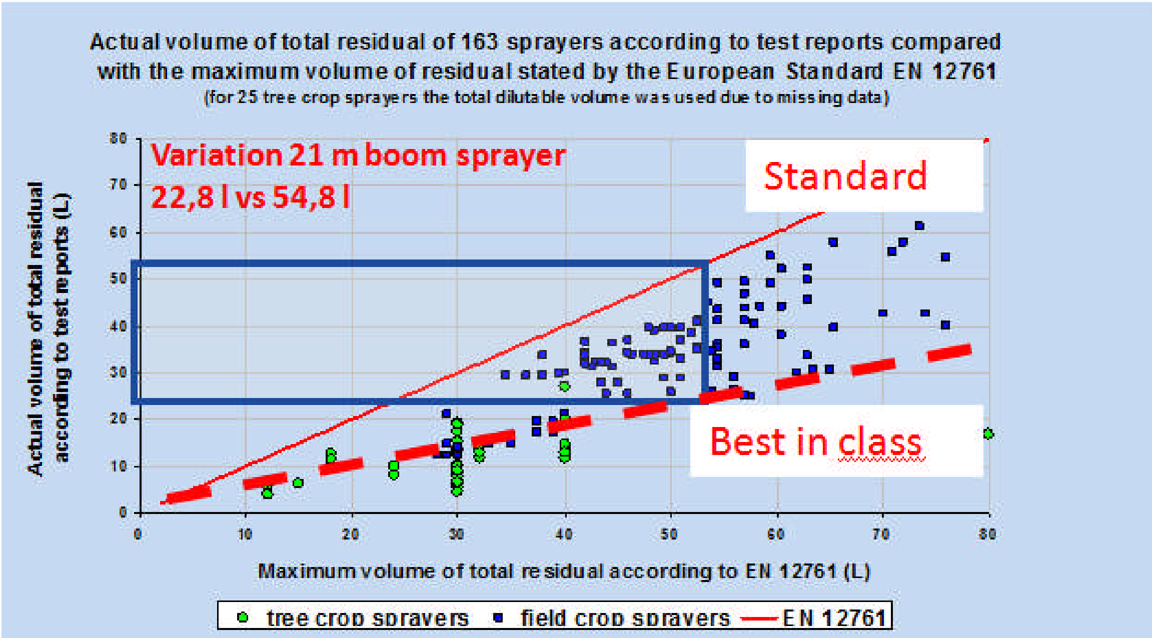


Figure 11:Analysis of ENTAM test of new sprayers on their compliance with the Standard EN 12761(C.Debear et al 2008).

Best sprayers performed already 50% better than suggested by the standard and therefore realize a significant risk reduction potential. Currently such differences are not strongly communicated and therefore not widely perceived.

ENTAM tests on rinse water tank capacities, suggested by the Standard EN1276, showed a weaker compliance of the tested sprayers with the standard (C.Debear et al 2008).

The fresh water capacity of the rinse water tank directly influences the dilution rate of the residual volumes, the cleaning efficiency and the possibility for outside cleaning in the field. The Standards EN12761 suggest a rinse water capacity of 10% of the nominal spray tank volume or 10 times the dilutable residual volume. Only 60 % respectively 70% of the sprayers tested complied with the standard (C.Debear et al 2008).

The rinse water tank is absolutely necessary to enable rinsing of the sprayer in the field, which is a generally accepted Best Management Practice (www.TOPPS-life.org). The aim should be to bring as little contaminated residual volumes back to the farm as possible. In France and Denmark recommendations allow farmers to leave the contaminated residual liquid in the field if dilution rates of 1 or 2% of the original spray solution can be achieved during the rinse procedure. These recommendations are considered effective risk mitigation measures.

Basically two rinse procedures are recommended (Figure 12/13)

a) Stepwise rinsing (triple rinsing: after each rinsing step diluted residual spray needs to be sprayed out in the field – stepwise dilution of residual volume)

b) Continuous rinsing (additional pump is needed to deliver rinse water via a rinse nozzle into the spray tank. The sprayer pump pushes diluted spray solution out of the sprayer – “logarithmic dilution”). Continuous rinsing has the advantage that it can be operated directly from the tractor, faster and more convenient for the operator. This procedure was explored in the TOPPS project and it stimulated the development of upgrading kids and new developments. (Reference: Cleaning Brochures **http://www.topps-life.org/web/expertcommunity.asp?cust=1&lng=en&m=15)**

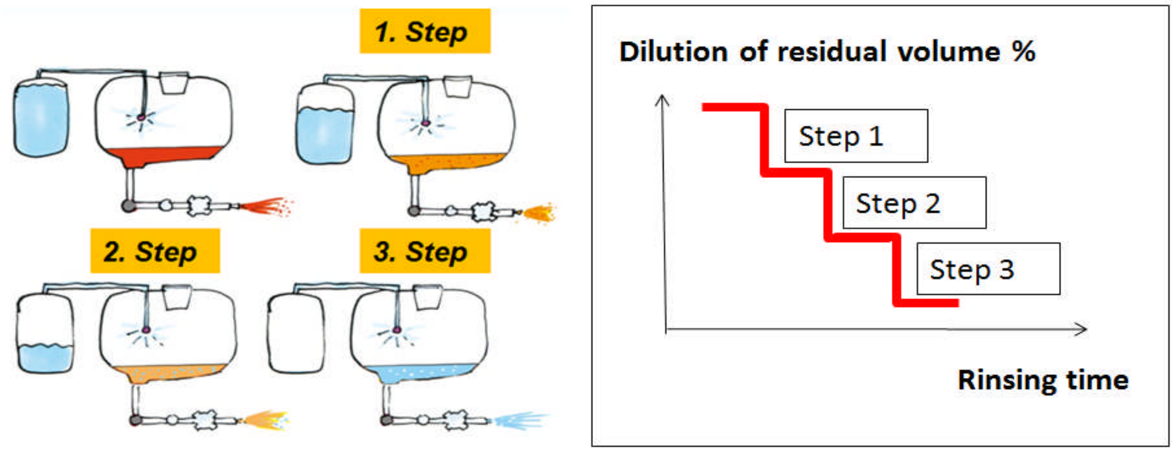


Figure 12: Stepwise rinsing procedure (Triple rinsing) for internal cleaning of sprayer tank.

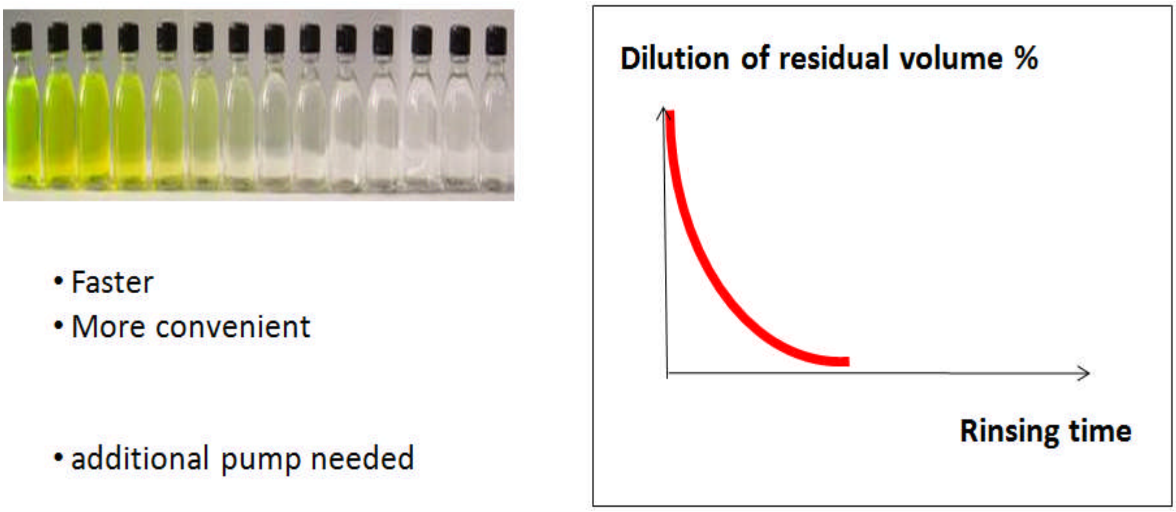


Figure 13: Continuous rinsing procedure for internal cleaning of sprayer tank.

Rinsing efficiency (measured as % dilution of residual volume) depends on the internal cleaning system (rinse nozzles), design of the tank and other devices. Tests show that achievable dilution rates of the residual volumes vary largely among different sprayers (Figure 14). It could be expected that further improvements are possible if development focus is given to this aspect. It would be an important information for operators to be informed by sprayer manufacturers, what dilution factor can be achieved following the operational procedures with the sprayer installed cleaning system.

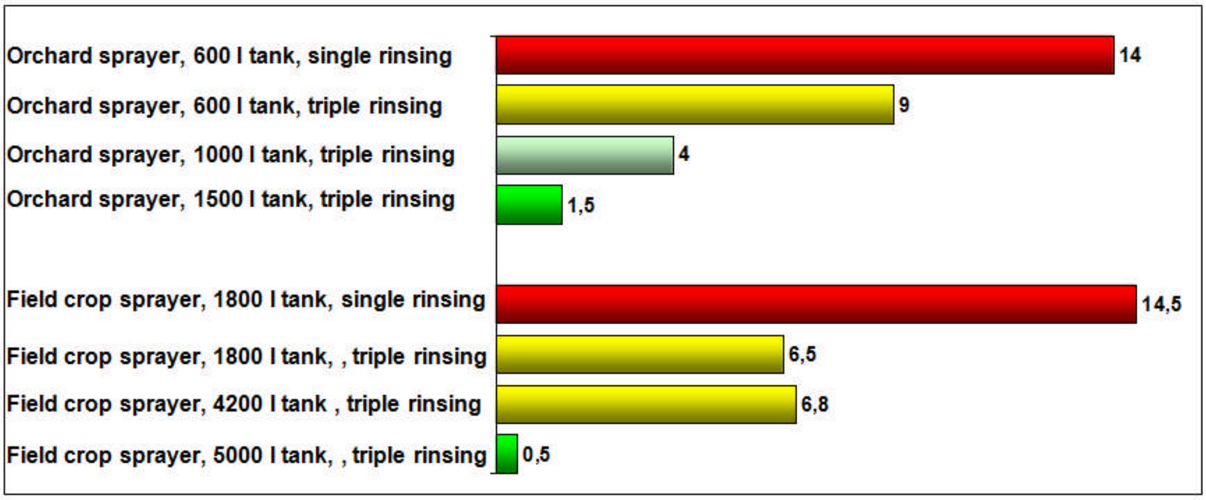


Figure 14: Rinsing efficiency between sprayers and rinse procedures: H. Wehmann JKI 2010 (single rinsing = all rinse water used in one step, triple rinsing = rinse water used in three portions)

4.2 Outside contamination

Especially sprayers with air assistance can have significant deposits of PPP on the outside. Orchard sprayers showed deposits between 0,33 and 0,83 % of the applied amount in Italy (Balsari et al 2006). In Belgium active ingredients on orchard sprayers were found between 82,5 and 207 g ai / ha in a spray season (Debaer et al. 2008). Currently devices to enable sprayer cleaning from the outside in the field are not very common (Figure 15).
Research has show that cleaning efficiency is much higher if cleaning occurs in the field when deposits on the sprayer are still wet.

Figure 15: PPP deposits on sprayer outside and cleaning device attached to the sprayer to enable field cleaning from outside.

4.3 Filling

TOPPS surveys in pilot areas indicate that more than 85% of operators fill their sprayers on their farmyard. These are often hard surfaces which are often not designed to collect any spills or accidental overflow of spray liquids. Also, unless triple rinsed,, empty stored packages can be a potential significant point source risk.
If filling is done on farm precautionary measures are recommended. The other option to fill the sprayer in the field requires less investment. Filling in the field is not very common and mainly used by big farms and contract sprayers, which can transport both water and PPP products to very distant fields.
There are two main aspects to distinguish
a) filling of PPP
b) filling of water
Sprayers offer attached induction bowl systems to reduce the risk of spilling PPP concentrate when loading the sprayer. These systems mostly carry devices to clean empty containers. TOPPS surveys indicated that these devices are quite common on new field crop sprayers in West - European countries but are less common in the South and East.
Such devices are not very commonly attached to orchard sprayers because narrow row spacings limit machinery widths. These sprayers provide PPP container cleaning devices in the strainers (inserted in the filling hatch). Further options especially for orchard sprayers (with higher filling holes) are not sprayer attached induction hoppers (self standing).

Water filling also offers opportunities for improvements. More than 85% of farmers indicated in the TOPPS surveys that they measure the amount of water to be filled with the help of the scale on the side of the spray tank. Research has shown that such scales are often not very precise and after some time of use the visibility is often impaired (Figure 16). Imprecise water measurements can increase the risk of ending an application with too much spray liquid still left in the tank.

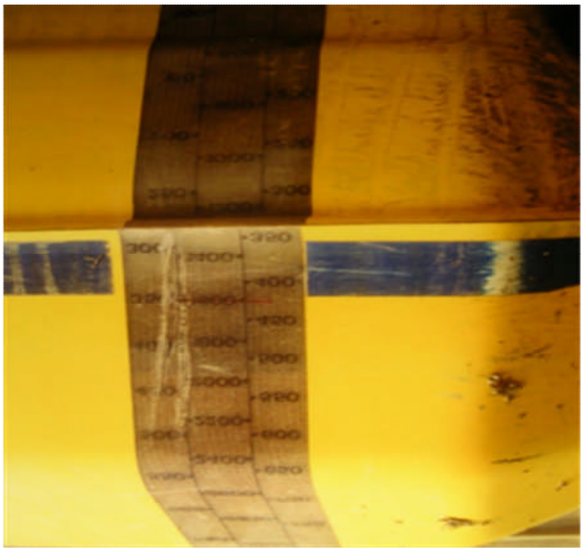


Figure 16: Measuring scale at the tank to determine correct water volume (impaired visibility)

Water induction should be possible without sucking in air, which causes foaming and increases the risk of tank overflow.
Another aspect is to avoid the contamination of any water resource (public network etc.) to make sure that no contamination can happen (intermediary tank, security valve to avoid backflow, etc).

4.4 Remnant management

Remnants are contaminated liquids brought back to the farm inside the sprayer (diluted or not diluted residual spray) or washing water from other cleaning operations (outside sprayer) or contaminated materials from maintenance operations (Filter, nozzle cleaning). The amount and concentration of the remnants is very much depending on the rinsing / cleaning processes done in the field after application. If the rinsing is done correctly and also the outside of the sprayer is cleaned in the field the amount of remnants is rather small. If this is not the case remnants can be a significant point source risk.
Sprayer design can contribute to risk reduction through technical solutions for easy collection of contaminated liquids, through designs to minimise potential spills. Also the amount of residual volume in the sprayer should be reduced to a minimum by sprayer design.

4.5 Spray losses + drift

Spray losses can occur during transport to the field and therefore careful inspection of tank hatch lids, hoses or nozzles for any leaking should be undertaken regularly.
Drift mitigation is especially a challenge in Orchards / Vine crops. In field applications drift reducing technology (DRT) is available and can significantly reduce the risk of drift. DRT is not yet sufficiently implemented across EU member states .The recommendations on Best Management Practices to reduce risk vary widely.
Drift mitigation can also be improved through devices which allow optimal adjustments of sprayers (f.e.deflectors to direct air flow) adapted to the changing development stage of the crop.

5. EOS – Methodology to evaluate the potential of technical solutions to mitigate losses of PPP to the environment

5.1 Evaluation model

The model links a risk analysis (example Figure 17) with the evaluation of capabilities of technical solutions to mitigate these risks. The evaluation follows a four step (in case of available aspects a five step) approach (example Figure 18)

> 1. Step
> EOS risk areas for field- and orchard sprayers weighted in % on their significance to reduce PPP losses. (Figure 9).
>
> 2. Step
> Problems to be solved by technologies have been identified and weighted (%) on the importance to provide a solution.
>
> 3. Step
> For solving the identified problems available technologies (general) were listed and weighted according to their potential to reduce risks.
>
> In some cases technologies were further analysed on some specific aspects where necessary. Example: The technology of the induction hopper rinsing was further analysed regarding the rinse liquid used (30%) and the installed device for the rinse system (70%) (Example figure 17). Aspects were only considered where a further specification was necessary. The EOS evaluation questionnaire in the web tool shows in which cases such aspects were considered. (Figure 19)
>
> Further information on the evaluation procedures and weightings, descriptions of technologies are given in the chapters (6.1 to 6.5)
>
> 4.Step
> For each defined technology available technical solutions were listed and evaluated on their potential to contribute to risk reductions. Technical solutions were scored on a scale 1 to 10 on their risk reduction "capabilities". (Mitigation score: 1 weak mitigation capability ... 10 currently best mitigation technologies).

The weighting factors on steps 1 to 3 are multiplied and can be seen as a value which reflects the risk mitigation potential of a technology. This factor multiplied with the mitigation score of a specific technical solution assess the contribution to the overall risk reduction potential (Figure 18).

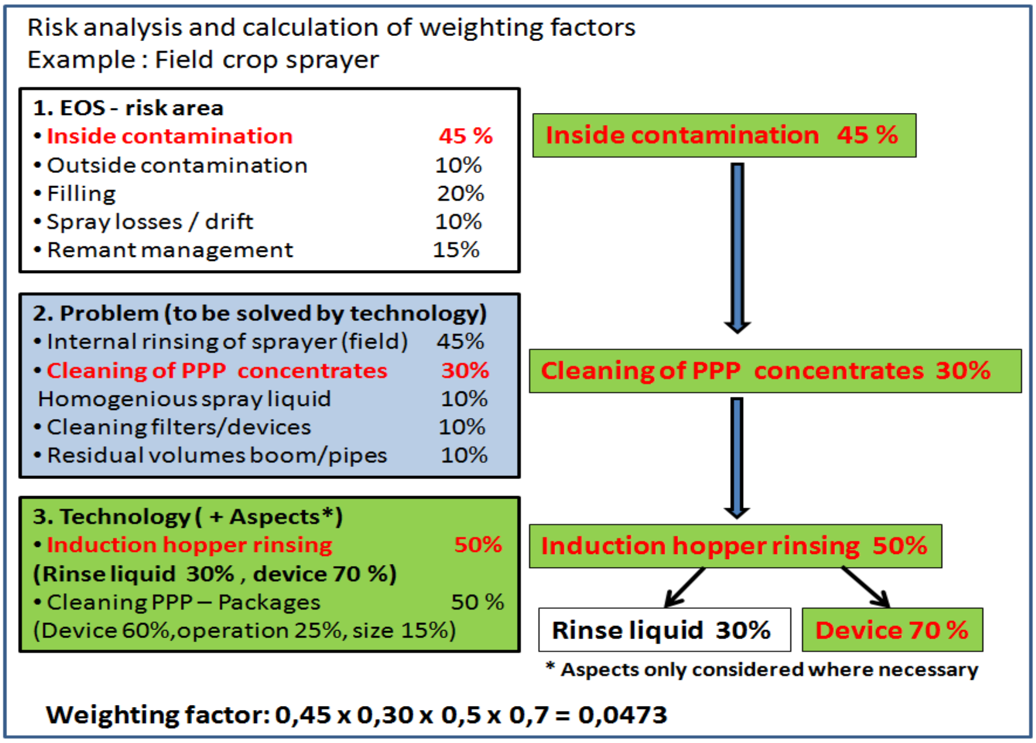


Figure 17: Calculation of risk factors to determine EOS values for selected / available technical solutions

The weighting factors on steps 1 to 3 are multiplied and can be seen as a value which reflects the risk mitigation potential of a technology in the context of the investigated EOS risk areas. This factor multiplied with the mitigation score of a specific technical solution determines its contribution to the overall risk reduction potential (Figure 18).

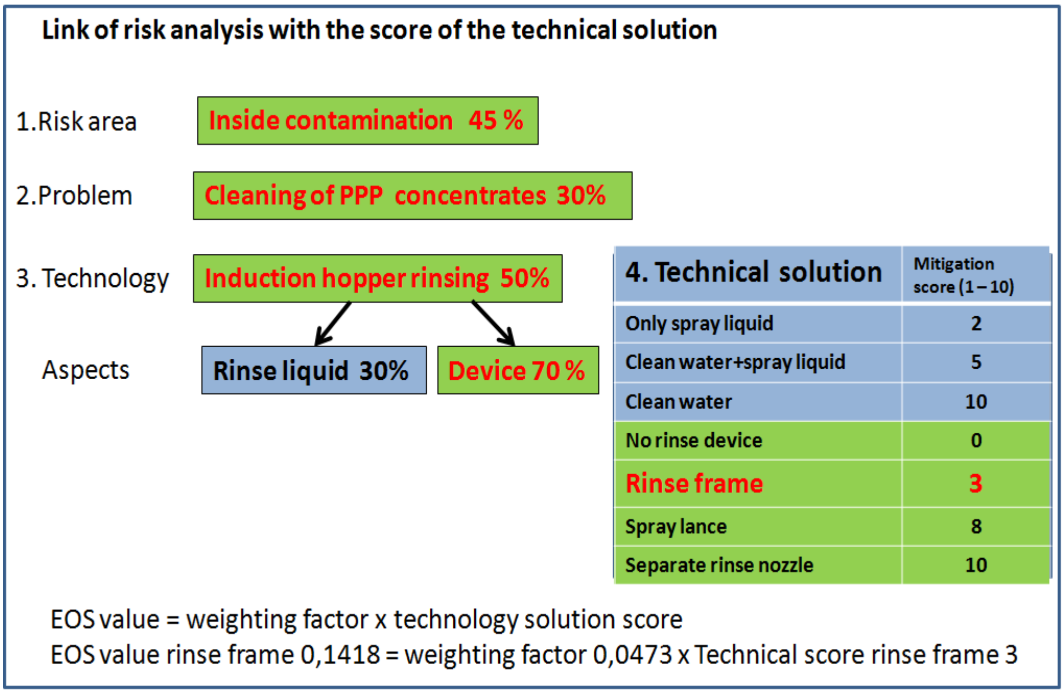


Figure 18: Multiplication of the risk factor with the selected technical solutions mitigation score determines the EOS – value for a specific technical solution

5.2 EOS index

EOS – values are calculated for each selected and for each respective best available technical solution. Both EOS values (selected and best available) are added and an EOS index ((selected technical solution / best technical solution) x 100) is calculated. The EOS index is expressed as a percent figure and shows how much a sprayer reaches the maximum achievable risk mitigation potential compared to currently available best technical solutions.

In the web based evaluation tool the EOS index is calculated along with the completion of the EOS questionnaire (Figure 19). A complete evaluation of a sprayer requires to go through a web-based questionnaire and to select 75 technical solutions out of 194 possibilities.
The EOS index is displayed in the EOS risk area button (Figure 20). A user of the evaluation tool can play with the different technical solutions available and can see how the EOS index is changing. It can be used in a similar way to a "configuration tool" as made available by car manufacturers when choosing a model. A total EOS index of 100 % would indicate that a sprayer is best in class in all criteria considering the areas in focus.

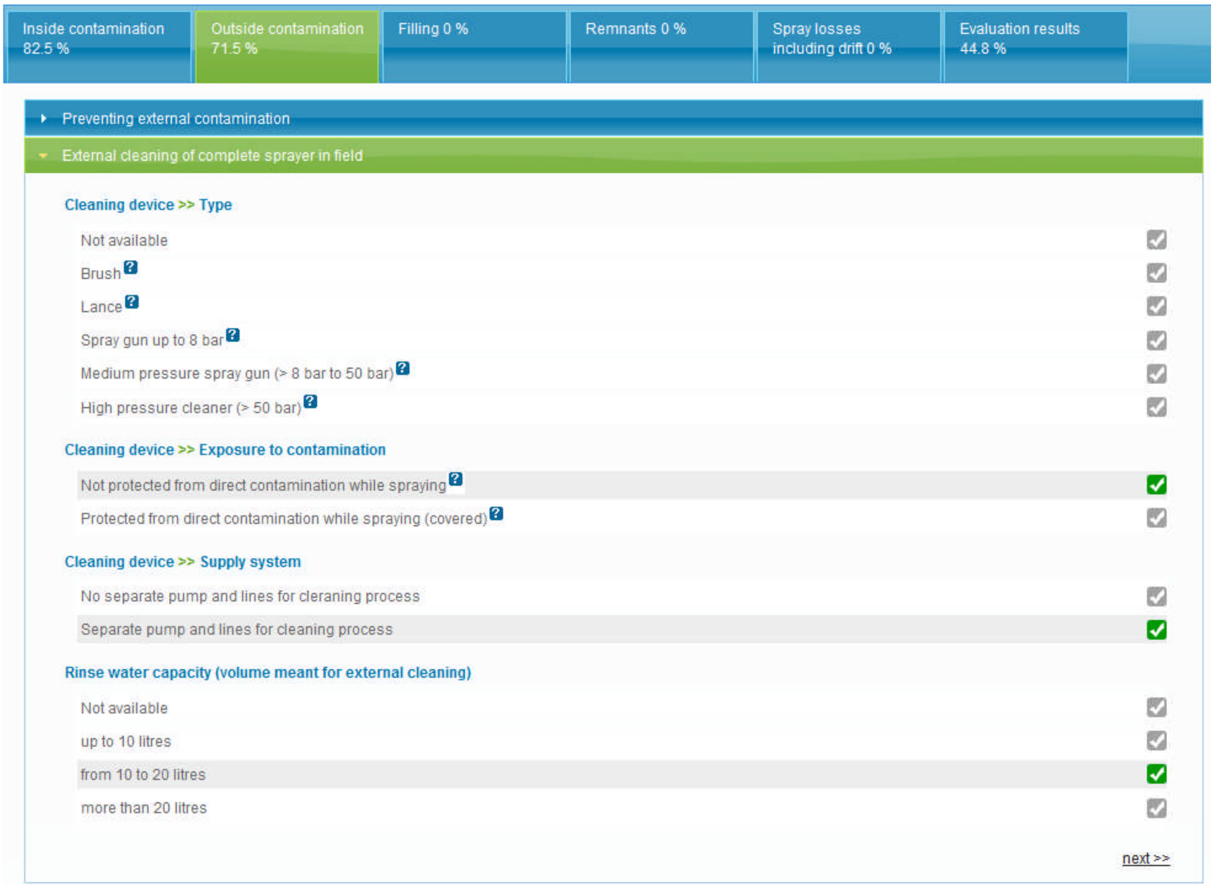


Figure 19: View on the questionnaire shown in the EOS evaluation tool, which need to be completed for a complete evaluation. (Buttons with question marks open a window with further explanations / pictures).

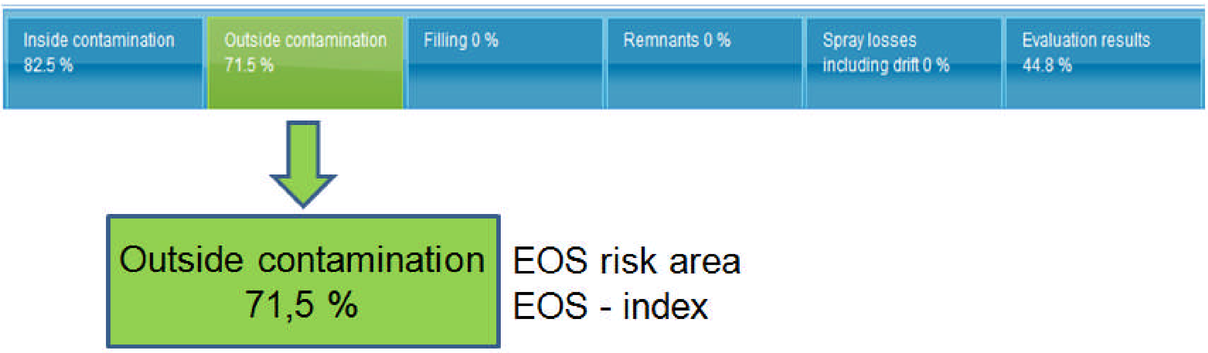


Figure 20: View on the web based EOS evaluation tool (EOS risk areas and display of EOS index)

5.3 EOS index communication

After the completion of the EOS questionnaire the evaluation results are displayed for each EOS risk area and a total EOS index by clicking on the button – Evaluation results (Figure 21).

Figure 21: Display of evaluation results after completion of the EOS questionnaire. EOS index expressed in %, stars will indicate the rating of the sprayer.

The table displayed not only highlights the areas where the technical solutions are already sufficient but also areas where technical solutions should be upgraded. It is hoped that this tool brings valuable information to all stakeholders concerned and helps to create the awareness necessary to enable a more sustainable use of PPP.
The EOS evaluation tool can be accessed under www.TOPPS-EOS.org, it is available in 9 languages and it addresses Field crop sprayers and Orchard sprayers.

6.1 Internal contamination - *EOS RISK AREA*

Internal contamination presents the most significant risk area; a risk area that is higher for field crop sprayers than orchard sprayers as more residual volumes remain in pipes, the boom and there is an assumed higher frequency of cleaning. In contrast, the spray liquid concentration in orchard / vine sprayers may be often higher than field applications as their sprayed water volume rates may be lower. Effective risk mitigation demands as little as possible diluted, [or contaminated], residual volumes are brought out of the treatment zone; a practice that is encouraged with regulations in Denmark and France that allow the draining out of all residual volumes in the last sprayed field if the original spray solution has been further diluted by a factor of 50 or 100 respectively.
Design and use considerations prompt the need for separate ‘weighted’ risk areas to be recognised for “internal contamination” of field crop and orchard sprayers [Figure 22].

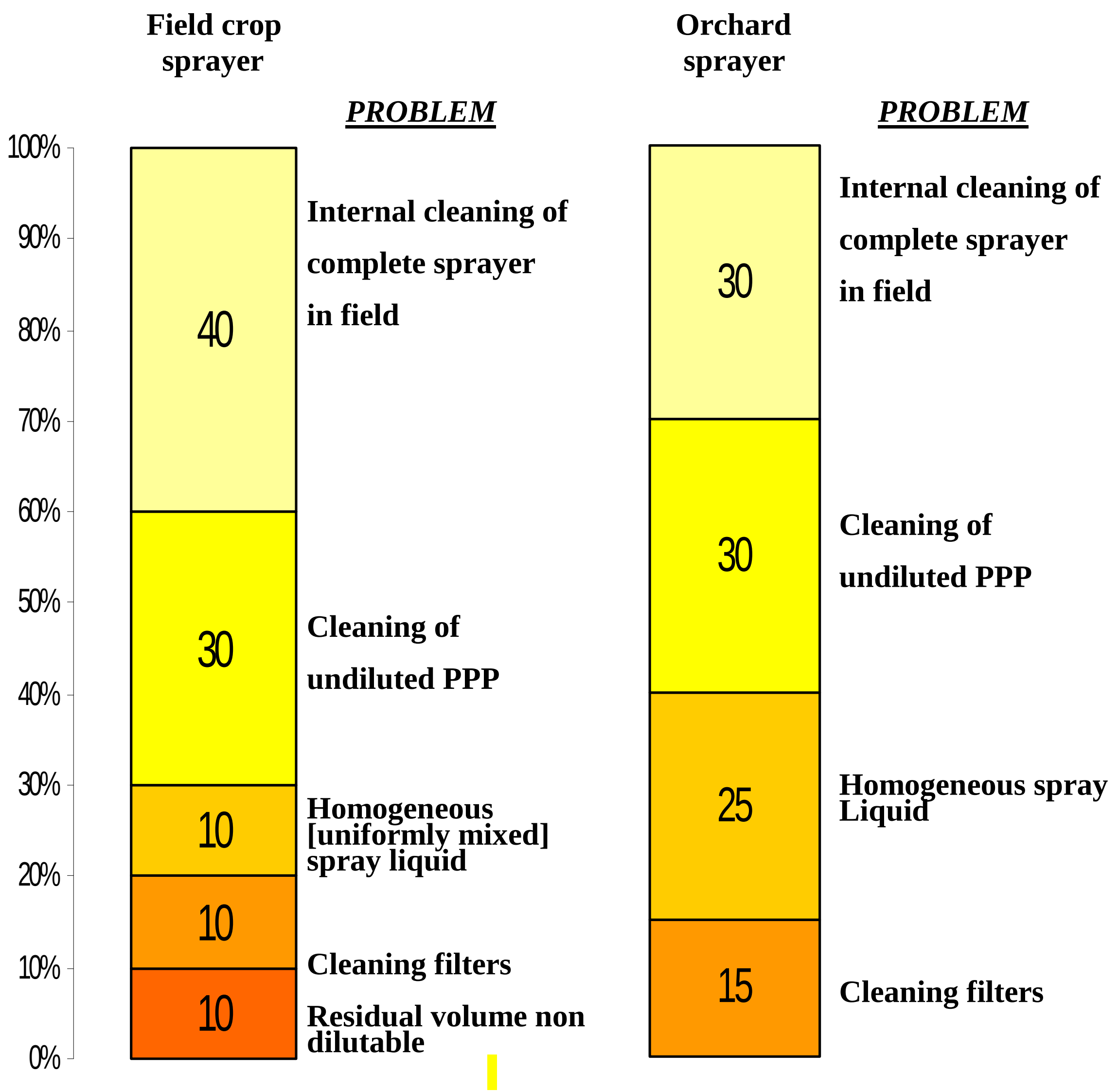


Figure 22: EOS risk areas for internal contamination: relative weighted risks (%)

6.1.1 Internal cleaning of complete sprayer in the field – *PROBLEM*

The internal cleaning capabilities of the sprayer are essential to the need to reduce the risks of surface and ground water contamination. Sprayer cleaning procedures should be made in an appropriate area of the field where the last application is made; a practice that ensures all the pesticide is restricted to its intended treatment zone. Efficient, in-field, internal cleaning is achieved by a combination of technologies that considers the availability of rinse water in adequate volumes, how it is used by the internal cleaning system and how that rinsing process is supported by favourable tank designs; design considerations that need be complemented by guidance on how to safely manage that used rinsing water after that cleaning process. Different sprayer designs may influence the volumes of residual spray liquid retained, their location and ease of removal and / or adequate dilution. These differences have prompted the overall ‘weighted risks’ of inside contamination of field crop sprayers to be 40 % but for orchard sprayers to be 30% [Fig 23].

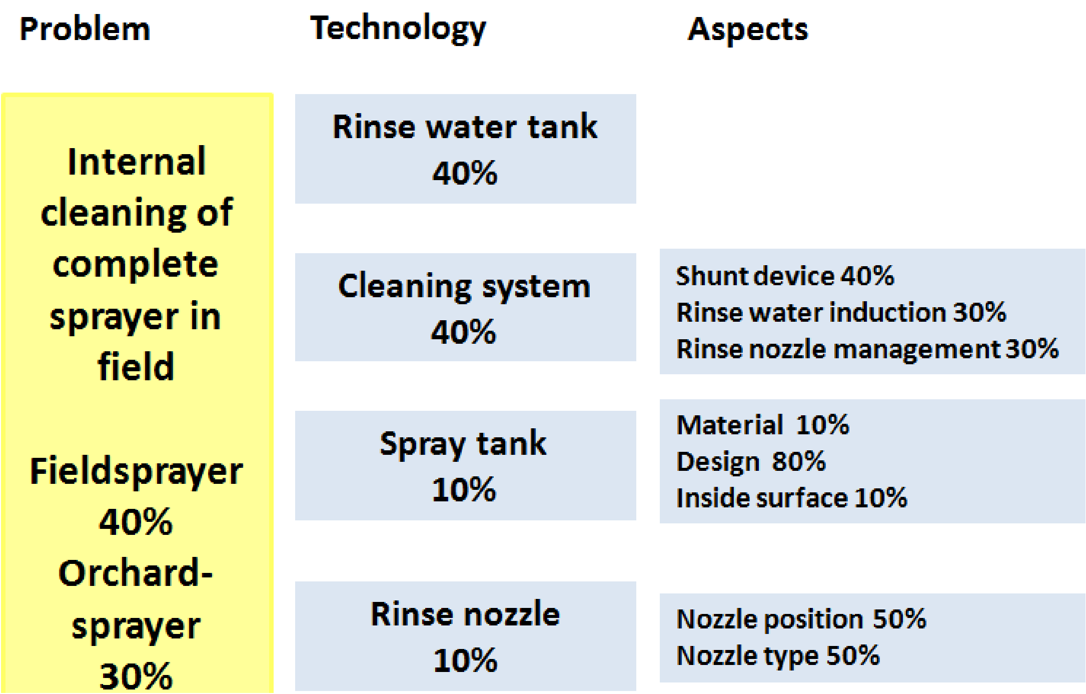


Figure 23: Identifying the problems, available technology and other aspects concerning the internal cleaning of complete sprayer; relative weighted risks [%].
Manifold and shunt device are synonymous

6.1.1.1 Rinse tank – *TECHNOLOGY*

The most important sprayer component for effective in-field cleaning is a rinse tank for containing clean water; a component that is essential for all environmentally optimized sprayers. Dedicated, on board rinse tanks must only be used for clean water and of a size to contain quantities that are sufficient for effective cleaning. New field crop sprayers are mostly equipped with rinse water tanks whilst orchard sprayers are less so. Rinse tanks should be integrated within the overall structure of sprayers to avoid being damaged by - or causing damage to – trees and other likely contact points.

Standard EN 12761-2,3

A water tank (or tanks) for rinsing the spraying equipment shall be provided except on mounted orchard sprayers of capacity less than or equal to 400l. This tank shall not be combined with the clean water tank for the operators use (see 5.10 of ISO 4254-6:2009). It shall have a volume of at least 10 % of the nominal tank volume or at least 10 times the volume of residual which can be diluted (see 2.2 of ISO 13440:1996). In the latter case, the volume of residual of tank shall be specified in the instruction handbook.

EN 12761-2: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

EN 12761-3: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.

6.1.1.2 Cleaning system – *TECHNOLOGY*

Appropriate circulatory systems are also crucial for effective cleaning with all aspects needing to be considered and environmentally weighed:

- Manifolds for liquid directional control 40%
- Rinse water induction 30%
- Rinse nozzle management 30 %

Manifolds for liquid directional control

A manifold with a three-way valve to allow effective cleaning procedures in the field enables rinse water to be directed through pipes / booms even when the main spray tank still contains prepared spray solution [Fig 24]. Dilution of the residual volume in the main tank is possible with one three-way valve located in the suction line [to change flows between the main tank and the rinse tank] and a second three-way valve that stops 'back flow' to the tank and redirects that flow to the suction line.

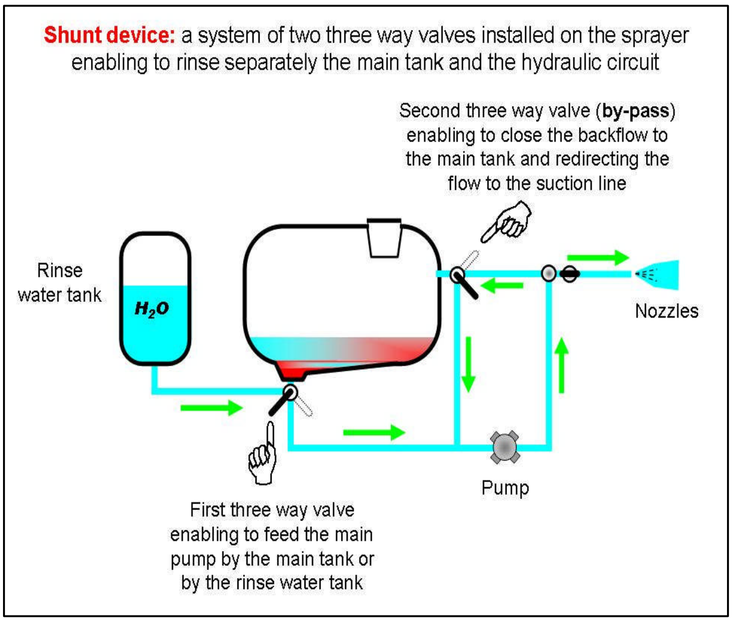


Figure 24: Manifolds used to optimise the emptying and rinsing of the sprayer
Shunt device = Manifold

Standard EN 12761-2,3

Water tanks shall be designed so that they can be connected with the equipment in such a way that the rinsing of the pipes is possible even when the tank is filled to its nominal volume. In addition, the dilution of the volume of residual in the tank shall be possible.

EN 12761-2: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

EN 12761-3: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.

Rinse water induction

Methods by which rinse water are induced into the cleaning system are also important; cleaning efficiency, for example, is influenced by how the rinse water is delivered (actively / passively) into the spray tank. Currently two main procedures are recommended: the multi-step rinse system that typically needs the use of the main sprayer pump and the continuous rinse system which requires a separate pump. These procedures are increasingly automated as their acceptance and popularity increases.

Continuous cleaning uses a separate pump to induce the clean water through rinse nozzles into the main tank as the operator sprays out the accruing rinse liquid. The continuous cleaning procedure requires the flow rate of the separate pump to be about 90 % of the output of all spray nozzles; a system that may have the advantage of being faster and more convenient for the operator.

Rinse nozzle management

Whilst the use of a spray gun or lance has been and may still be used, installed internal tank cleaning nozzles, that can be operated manually or remotely, are more convenient and safer to use. Continuous cleaning procedures must adjust rinse nozzle flow to the spray nozzle output; an output that will change with nozzle size, numbers and pressure used.

6.1.1.3 Spray tank – *TECHNOLOGY*

Many features of the main spray tank are critical to the effectiveness of how they – and the complete sprayer system – may be cleaned. Design is the most important aspect. Dead areas [that is where the spray liquid is not agitated or cannot be pumped out] in the tank should be avoided as they may also restrict access and effectiveness of the rinse water as well as retain sediments of PPP. Tank construction build material is important for, as an example, supportive structures inside the tank to make it more stable, could result in “dead areas”. In addition, the tanks surface of the inner walls need be capable of being readily cleaned and avoid excessive hold back of spray solution. All three factors are considered and environmentally weighed in the evaluation of the spray tank:

- Material 10%
- Design 80%
- Inside surface 10%

Material

The most commonly used materials to make sprayer tanks are fibre glass, polyethylene and stainless steel. One limitation of fibre glass is the need for internal surge walls which are necessary for bigger tanks to ensure their physical stability. Polyethylene is the most used material for spray tanks for it is durable, physically stable [even with bigger tanks] and – as with fibre glass – can be shaped to meet most needs of this vital component. Stainless steel is very durable but imposes some restrictions on design.

Design

Spray tanks with regular shapes allow a more intensive cleaning of the inner walls by the rinsing water jet. Irregular shapes, where dead areas and angles encourage the formation, retention and more difficult removal of residues of PPP, need to be avoided. Consider, for example, the tunnels that house the fan drive within tanks of orchard sprayers, that will most likely lead to extensive dead, non cleaned, areas (Fig. 25).

Figure 25: Tank with regular shape where all surfaces can be easily reached by the rinse water spray jet

Internal surfaces

Internal surfaces of main spray tanks need be smooth and non- liquid retaining. The degree of this surface wall roughness may be more dependant on the production process rather than the build material.

> ***Standard EN 12761-2,3***
>
> *Depth of roughness of inner and outer walls of the tank shall be such that Rz<= 100µm as specified in ISO 4287, and measured according to ISO 4288.*
>
> *EN 12761-2: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers*
>
> *EN 12761-3: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.*

6.1.1.4 Rinse nozzle – *TECHNOLOGY*

The efficiency of the cleaning process is much influenced by how rinse water is dispersed through the rinse nozzle; their efficiency at reaching all areas in the spray tank to effectively remove spray deposits is vital. Their importance has encouraged many improvements that are increasingly offering a more ensured and thorough cleaning of the inner surfaces of the spray tank. The number of nozzles, their type and their position need to be combined in a way to fully optimise the cleaning process of the tank within which they are fitted. The contribution of two main factors - relating to rinsing nozzles and their use - are considered and environmentally weighed:

- Type 50%
- Position 50%

Type of rinse nozzle

Test results have showed that rotating nozzles and static nozzles achieve similar cleaning effects. However, many points on their robustness and efficiency must be noted. Rotating nozzles are prone to stop rotating after a certain time of use; dirt and product residues can cause problems with the bearing. In addition, the impact energy of the water jet from the nozzles is crucial to the removal of some forms of deposits. Nozzles normally used for rinsing of product containers are constructed with the purpose to rinse surfaces at a distance of about 10 cm. Rinse nozzles for spray tanks need to be adapted to the design of the spray tank and should work with higher energy water jets to effectively reach more distant surfaces (Figure 26).

Good results have been achieved with several rinse nozzles mounted on a rotating axle to better reach every internal surface within the complete (often longer) tank. (Figure 27).

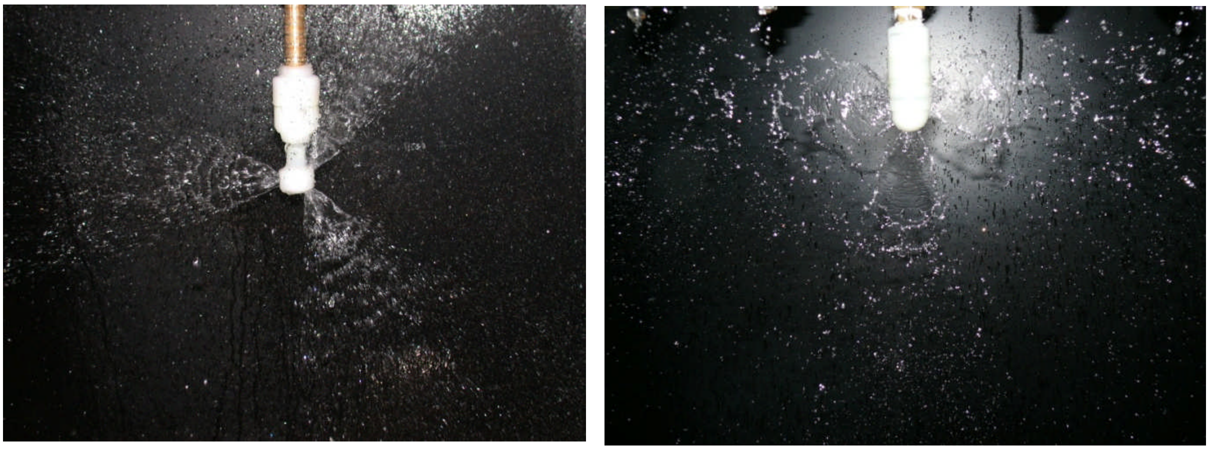


Figure 26: Rotating rinse nozzle with high energy water jets (Left) and low energy rinse nozzle normally used for rinsing of product cans (Right).

Figure 27: Rinse nozzles mounted on a rotating axle that can effectively reach all inner tank surface using high speed impact water jets

Position

The position of the rinse nozzles must be chosen in a way that their emitted clean water can reach all areas of the tanks internal construction. It should be considered that, for example, rinse nozzles fitted close to internal hoses and filling hole strainers will lead to shading [non contacted] areas in some areas of the tank. Similar, poor rinsing, situations may occur in tanks with internal surge walls that are built to increase tank stability.

6.1.2 Cleaning of undiluted plant protection products – *PROBLEM*

Contamination from undiluted PPP during the filling procedure can be a huge risk for point source pollution. Users are requested to work very carefully and take all necessary precautions to avoid such incidents. Important technical solutions such as induction hoppers that are commonly fitted to field crop sprayers are developed to make the PPP filling easier, quicker and safer. Induction hoppers allow the PPP to be poured into a funnel-shaped opening at a comfortable working height and, in so doing, avoids the need for the operator to climb up or over his sprayer to access the main filling opening. The PPP may also be directly induced - without premixing - using hoppers into the main tank or may be premixed with water. Most hoppers offer a suitable system or procedure to clean the induction hopper of any retained PPP on their internal surfaces. Most induction hoppers also have a facility that rinses PPP containers clean. Effectively cleaned and drained containers are an essential risk mitigation measure and a prerequisite to participation in the recycling schemes of empty containers, which exist in many countries.

Orchard sprayers are seldom equipped with induction hoppers; the height of the main tank filling position is, often, not so high as with field crop sprayers. There are other constraints to their fitting too; the narrow row spacing of orchard / vine crops may not allow the attachment of induction hoppers to the sprayer. The evaluation of these structures and the environment weights given to these technologies and their specific aspects are shown in Figure 28.

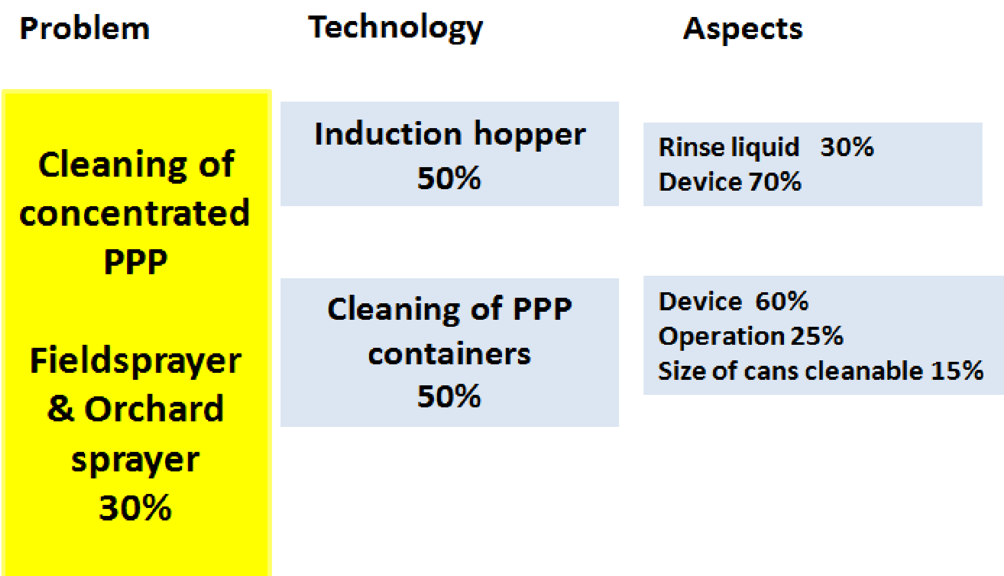


Figure 28: Evaluation structure, weights of technology and their specific aspects relating to the problem of cleaning undiluted PPP.

6.1.2.1 Induction hopper rinsing – *TECHNOLOGY*

The rinse liquid used in induction hoppers and the construction of the rinsing device need to be considered. Systems for induction hopper rinsing use either the preparing spray liquid for that rinsing or clean water supplied via the sprayer or from an external source. The design of the induction hopper determines how efficient the cleaning procedure can be made. For the evaluation of the induction hopper rinsing, the following aspects are considered and environmentally weighed:

- Rinse liquid 30%
- Device 70%

Standard ISO 21278-2

Washing of the induction hopper shall be possible using clean water, either from a clean water tank on the sprayer or from an external source.

ISO 21278-2:2008 Equipment for crop protection. induction hoppers. Part 2: General requirements and performance limits

Rinse liquid

The use of clean water [rather than the preparing spray solution] for the rinsing of the induction hopper is preferred as this is more effective and enhances the protection of the operator and the environment. It is recognised that during the filling process there is normally enough clean water available for cleaning the hopper and this should be used. Where water has been used from the clean water tank, that used, should be refilled after completion of the filling procedure.

Rinsing device

Many different devices exist to clean the internal surfaces of hoppers after use. These systems can vary from rinsing rails, frames to rinsing nozzles. However, common to all such fitted devices, is the need for the hopper to be closed tightly during the cleaning procedure to avoid risks of contamination of the work environment. Although the use of spray lances or hoses is not uncommon, it is clear that the operator – and his work environment - must avoid all risks of exposure to splash (Figure 29).

Figure 29: Rinse nozzles for induction hoppers allow safe cleaning of internal surfaces.

Standard ISO 21278-2

The amount of test material residue in the induction hopper tank after washing carried out according to clause 6.7.2 of ISO 21278-1 shall not exceed 0,10% of the induction hopper nominal volume.

ISO 21278-2:2008 Equipment for crop protection. induction hoppers. Part 2: General requirements and performance limits

6.1.2.2 Cleaning of PPP containers – *TECHNOLOGY*

Devices used for cleaning of discharged PPP packages are evaluated from three different aspects: the cleaning device itself, the necessary operational procedures and the possibility to clean most available package types and sizes. These devices should encourage their easy and efficient use immediately after the emptying of the PPP package. Operating procedures should also be easy and safe for both user and environment. Container sizes up to 20 l should be possible to clean. For the evaluation of the container cleaning PPP devices, the following aspects are considered and environmentally weighed:

- Device 60%
- Operation 25%
- Opening size 15%

Standard EN 12761-2,3

Devices for cleaning crop protection product cans, when provided, shall be designed so that the volume of residue after cleaning is less than 0,01 % of the nominal can volume.

EN 12761-2: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

EN 12761-3: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.

Device

Container cleaning devices – as a component of a sprayer - are either dedicated cleaning nozzles in the induction hopper or main tank strainer or with the use of spray lances attached to the sprayer (Figure 30)

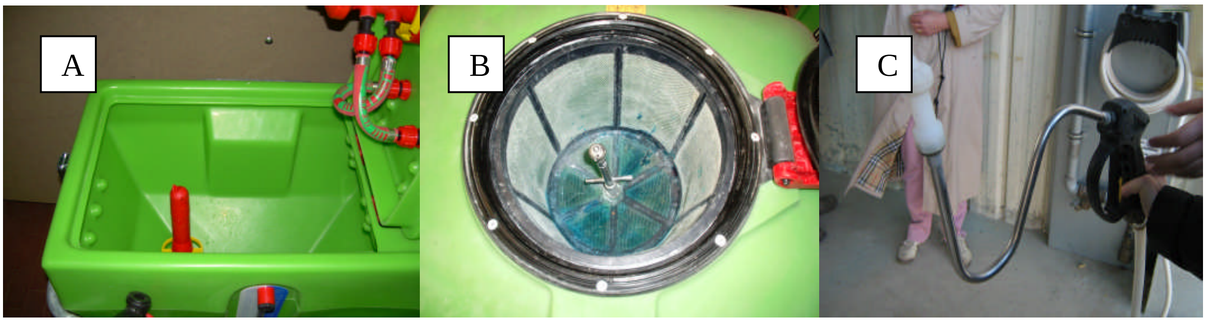


Figure 30: Different devices for cleaning PPP containers.
***A**: built-in in induction hopper* ***B**: built-in in filling hole strainer* ***C**: attached spray lance*

Operation
Two different principles for operating container cleaning devices can be distinguished: a shut-off valve operated by pushing down the container or the use of a separate, hand operated, valve. In both cases, the valves should be constructed to stop any accidental or incorrect operation. An advantage of the pushed-down valve is that it allows easier handling; especially for larger, heavier containers when both hands can be used to hold the container in the rinse position (Figure 31). The disadvantage is that some residues inside the container – located near the opening and at more distal points – can be difficult to rinse, as the container cannot be moved up and down. For both operating principles, the container cleaning efficiency depends on the nozzles working angle, water jet impact force and contacted area. Working angles between 200 and 360° are believed to be more efficient as it is considered that the wider working angle ensures direct rinsing with water in all inner areas of the container.

Figure 31: Use of a push-down valve for rinsing of an empty container

Size
PPP containers vary in sizes ranging up to capacities of 20 litres. The efficient and safe operating of the induction hopper - including the effective functioning of the rinse nozzle - should adequately cope with all these container sizes.

6.1.3 Homogeneous spray liquid – *PROBLEM*

Effective cleaning of a sprayer is, in part, also dependant on the production of a homogenous (that is when PPP is uniformly dispersed) spray liquid. PPP that do not form true stable solutions tend to more readily sediment out of the spray liquid. As sprayers may be used for many hours containing the same spray liquid, there can be solid deposits of sediment if the agitation system is not effective or reliable; a concern that may be increased with lower water volume use and the trend towards bigger spray tanks. Poor agitation may cause the PPP concentration in the residual volume to be

increased and the required optimal dilution factors for the residual volume may not be achieved. These inadequacies increase the risk for point source contamination if the residual volume is brought back to the farm.
Two aspects are evaluated: the agitation system and the regulation of the agitation flow rate. The weights for orchard sprayers are estimated higher than for field crop sprayers because most orchard sprayers have enclosed drive shafts to propel their fans that are positioned through the spray tank; a design consideration that changes the tanks bottom shape and, thereby, reduces its agitation efficiency (Figure 32, 33).

Figure 32: The fans drive shaft is located through the tank and reduces the agitation efficiency.
Example : Orchard sprayer

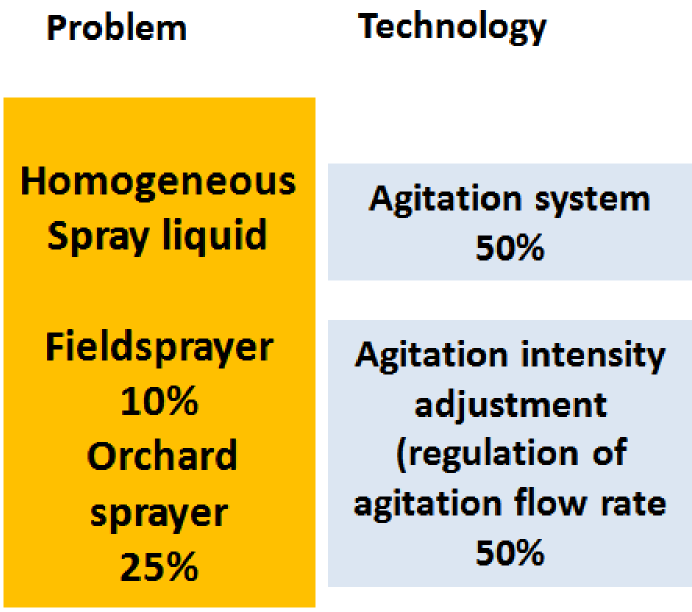


Figure 33: Evaluation structure and weights for the technology used to consider the needs for maintaining a homogeneous spray liquid

6.1.3.1 Agitation system – *TECHNOLOGY*

ISO Standard 5682-2 requires that the performance of the agitation system be tested by measuring the sedimentation rate of a copper oxychloride spray mixture in the spray tank. Best agitation systems are able to quickly reach a uniformly mixed and stable solution and to restore that intended concentration quickly after a period when the sprayer and its agitation system has not been used.

The design of the agitation system will also influence the amount of residual volume left in the sprayer.

<u>Standard EN 12761-2,3</u>

Tanks shall be equipped with devices (e.g. agitators) to ensure an even concentration of mixture. The maximum allowable deviation is 15 % when tested in accordance with ISO 5682-2.

EN 12761-2: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

EN 12761-3: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.

6.1.3.2 Agitation intensity adjustment – *TECHNOLOGY*

Equally important to the agitation system itself is the ability to adjust the intensity of agitation. The liquid flow rate used for agitation should be regulated according to the spray liquid volume in the tank. For lower filling levels in the tank, less agitation may be needed. Indeed, the agitation should be capable of being closed (manually, see figure 34, or automatic) when the remaining spray liquid volume falls below a certain level, to help ensure all the spray liquid (as far as possible) can be pumped out, the residual volume is minimal and excessive foaming - by air induction –is avoided.

Figure 34. Turning off agitation- when main tank volumes of PPP solution are low - reduces the retained residual volume.

6.1.4 Cleaning of filters – *PROBLEM*

Best management practices recognise the need for regular maintenance procedures to check and clean the filters. PPP - especially if mixed with other products or are poorly formulated or agitated - can cause clogging that may block the filters. The design of the filters should permit easy access to the sieves or gauzes and not allow any spills during the maintenance procedures. Filters cleaning problem are evaluated lower (10%) for field crop sprayers than for orchard sprayers (15%); an assessment influenced by the more easy access to the filters on field crop sprayers. The following aspects are specifically considered: Type and positioning of the filters in the suction and pressure lines and the total number of filters. From an environmental standpoint, the less filters necessary the better (Figure 35).

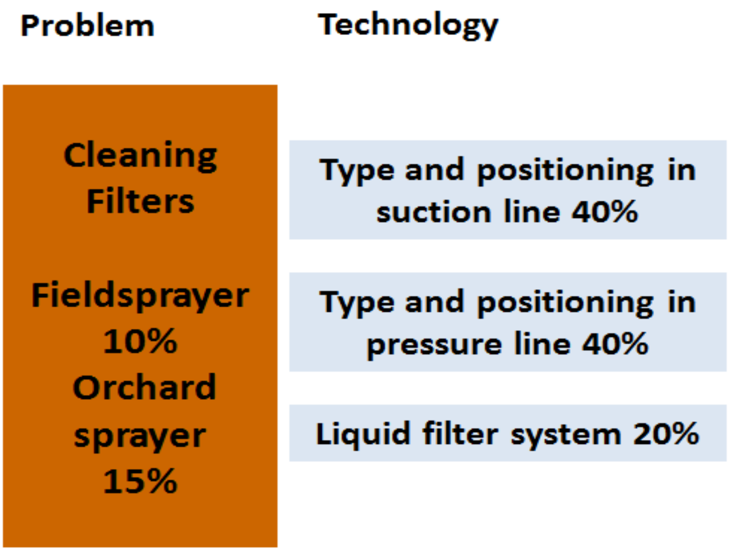


Figure 35: Evaluation structure and weights of technology for the problem of cleaning filters

Standard EN 12761-2,3

Sprayers equipped with a positive displacement pump shall have a suction filter.
On the pressure side, the liquid going to the nozzles shall be filtered by means of central filters or filters in the lines of spraying sections. The mesh size of filters shall correspond to the size of nozzles fitted on the sprayer. This applies also to nozzle and pump filters.
Blockages shall be indicated to the driver, for example by an appropriate positioning of the central pressure filters and pressure gauge.
Filters shall be easily accessible and filter inserts shall be removable. For quick cleaning the filter tissue of the insert shall be easily accessible.
It shall be possible, with the tank filled to its nominal volume, to clean central filters without any spray liquid leaking out except for that which may be present in the filter casing and suction or pressure lines.

EN 12761-2: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

EN 12761-3: 2001. Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.

6.1.4.1. Type and position of suction filters – *TECHNOLOGY*

The volume of spray liquid left in the filter housing depends on its type and positioning. If designs are not environmentally optimized, spills may occur when the filter housing is opened for inspection and cleaning. The opening, for example, of filters positioned horizontally, may cause losses of liquid from the housing that will increase risks to operator and environment. Risks can be largely avoided if a drain valve is fitted to the filter housing to drain the spray liquid before opening the filter. Another possibility to mitigate the loss of liquid is a vertical alignment where the housing can be opened from its top without loss of contaminated liquid (Figure 36)

Figure 36: Vertically positioned filters allow the opening of the filter house without spills

6.1.4.2 Type and position of filters in pressure line – *TECHNOLOGY*

Many filters that are integrated into pressure lines are constructed for self cleaning (Figure 37). Retained, non dispersed, particles on its filter inserts are continuously rinsed off by a liquid stream to be routed through an additional hose back into the main spray tank. Suction filters should address similar considerations.

Figure 37: Self cleaning filters in pressure lines reduces maintenance checks on other filters and nozzles

6.1.4.3 Liquid filtering system – *TECHNOLOGY*

Reliable functioning of a sprayer requires filters to protect that system and ensure optimised nozzle performance. However, each filter may pose a risk for point source pollution whenever maintenance is needed. Today, modern sprayers - using clean water sources, better PPP formulations and spraying under normal conditions – are claimed not to risk their machine or its performance when just using one suction filter and one pressure filter; an environmental benefit that can be gained through the avoidance of excessive filtration systems and better reliability.

6.1.5 Residual (not dilutable) spray liquid in hoses and pipes - *PROBLEM*

Field crop sprayers, in particular, may retain considerable residual volumes of PPP spray solution in their booms and their supply pipes. Conventionally designed booms cannot dilute the liquid - still retained after spraying has ceased - between the boom section valves of the control unit and the nozzles. In consequence, the only way to remove this retained spray liquid is to add water to the main tank and use that liquid to pressurise that solution out through the nozzles. This inability to remove – as part of normal spraying procedures - all the spray liquid must be considered in the cleaning process as it may cause a possible risk for the environment.

6.1.5.1 Boom supply / dimensions – *TECHNOLOGY*

Improvements to boom supply pipes - and their dimensions [width, length] used – have greatly minimized residual volumes in recent years. In addition, the introduction of systems with continuous re-circulating flow from booms back to the spray tank have done much to improve in-field cleaning performance of sprayers (Figure 38). Re-circulatory systems have several advantages: at the start of the application in the field, the nozzles may immediately be primed with the intended concentration of spray liquid. In addition, the higher and more continuous flow rates in the booms [even when not spraying] ensures the PPP solution is constantly agitated. During the cleaning process, all spray solution in booms and their supply pipes are returned to the main tank and diluted. Further developments use compressed air that is directed to blow through pipes and booms to still further reduce the possibility for any retained PPP to remain.

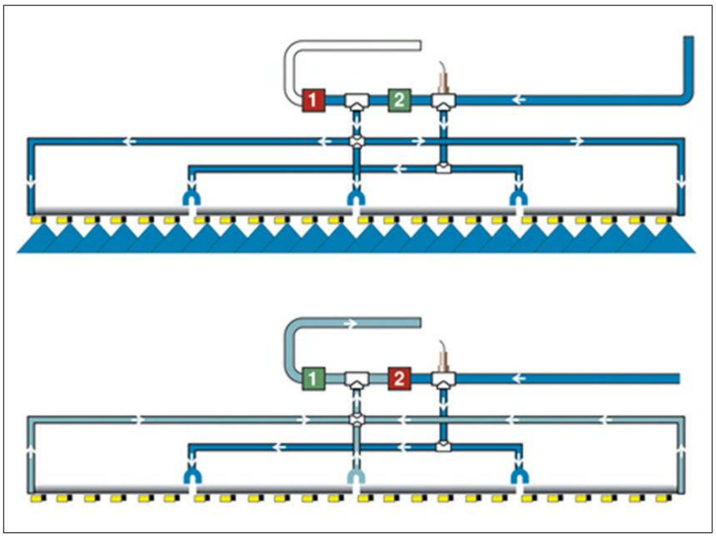


Figure 38: Boom re-circulation systems improve the supply of the spray nozzles at the start of the treatment and can minimise the non- dilutable part of the residual volume.

6.2 External surface contamination – *RISK AREA*

Contamination of the outside of the sprayer with spray liquid cannot be avoided; many factors, such as wind and weather, influence the rate of contamination and their location on the machine. Research has shown that orchard sprayers, in particular, with air assistance directed to spray upwards and / or laterally can cause significant deposit levels. Risks from external contamination are, therefore, weighted 10% for field crop sprayers and 20% for orchard sprayers in these EOS tables. External cleaning, as with internal cleaning, of the sprayer is best done in an appropriate area within the last treatment area and should be immediately done when the deposits have not dried and hardened. Sprayers are increasingly being offered with external cleaning equipment and adequate clean water supplies to make this task more routine for operators and safer for the environment. Differences between orchard and field crop sprayers are reflected in the values given (Figure 39).

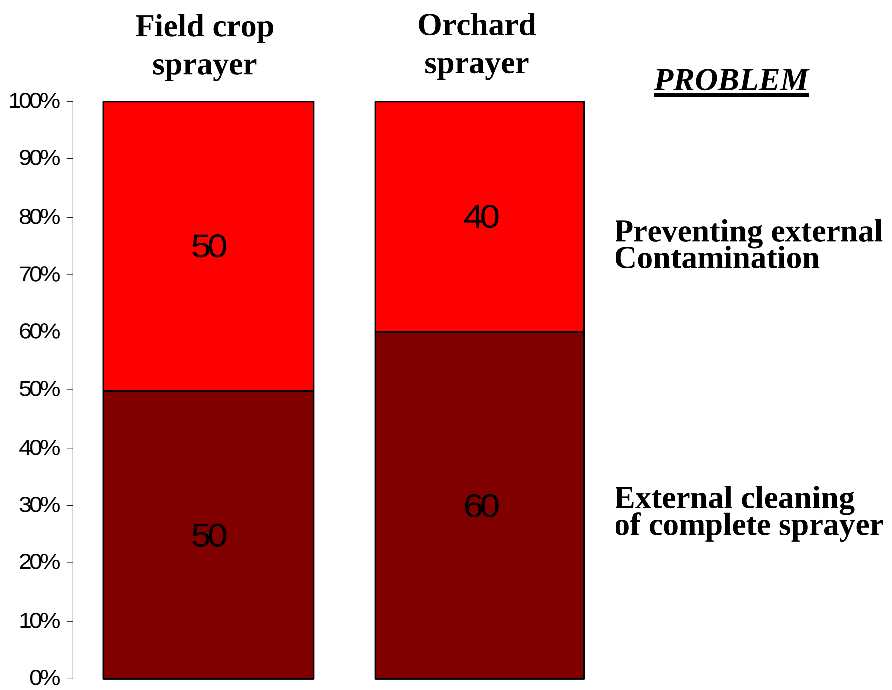


Figure 39: Problems related to the EOS risk areas for external surface contamination and their evaluated weights (%) for field crop and orchard sprayers

6.2.1 Preventing external contamination – *PROBLEM*

The external contamination of sprayers (and their prime movers) cannot be prevented entirely but different measures and adjustments influence the external contamination risk. In addition, the lack of awareness with many sprayer designs has left concealed areas that make cleaning less efficient especially when clean water supplies are limited. It is now recognised that finer droplets lead to higher deposits on the external surface of a sprayer than coarser droplets and, so too, may the use of higher spray solution concentrations. Perhaps, more importantly, the use of upwardly and/or laterally directed air-assistance induces higher deposits. These conditions of use are all closely related to orchard sprayers to, thereby, prompt the need for their higher weighted bias compared to that for field crop sprayers (Figure 40).

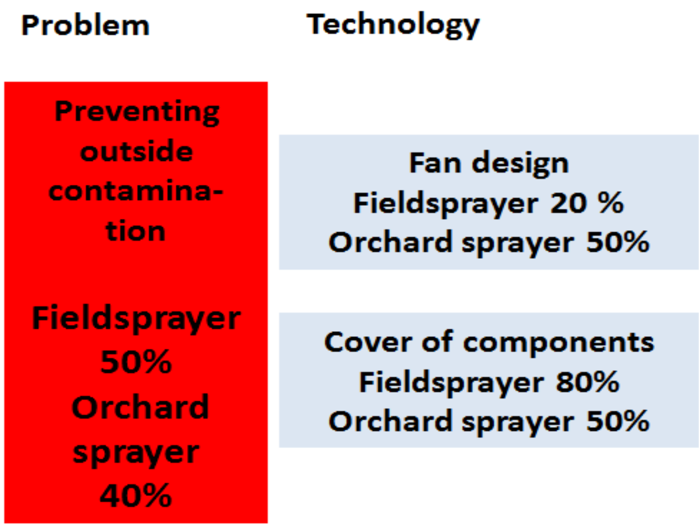


Figure 40. Evaluation structure and weights of technology for the prevention of problems related to external surface contamination

6.2.1.1 Fan design – *TECHNOLOGY*

The distance between the air inlet and the position of the spraying nozzles when related to the driving direction is an important aspect that influences the sprayer's contamination risk. Air inlets that are very close to the nozzles suck in more spray liquid droplets – to contaminate the fan and its housing - than an air inlet that is further away from of the nozzles (Figure 41).

Figure 41: Air inlet close to the nozzles

6.2.1.2 Covers on components – *TECHNOLOGY*

The use of shields to cover the sprayer – as well as 'cleaner' [more stream lined] designs - may be effective precautionary measures to reduce overall contamination and ease outside cleaning procedures. (Figure 42)

Figure 42: Shielded, smoother lined, sprayers are more easy to clean

6.2.2 External cleaning of complete sprayer – *PROBLEM*

External cleaning of a sprayer in the field needs the availability of both appropriate equipment and adequate volumes of clean water (Figure 43).

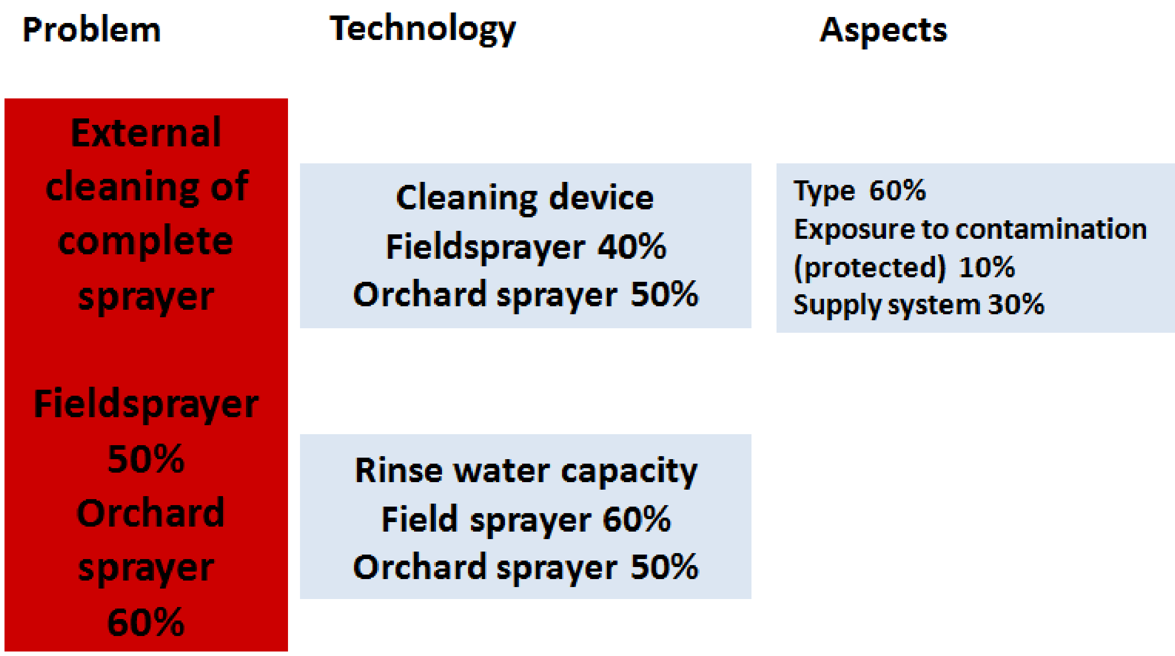


Figure 43. Evaluation structure and weights of technology and aspects relevant to manage the problem of external cleaning of sprayers

6.2.2.1 Cleaning device – *TECHNOLOGY*

Different external cleaning devices, such as brushes, spray guns and lances, are offered by manufacturers (Figure 44). Whilst all such means are considered suitable to remove the deposits from the external surfaces, they may vary in their use of rinse water, time consumption and cleaning efficiency. Evaluation procedures for such cleaning devices, must also consider any likely exposure from direct and indirect contamination and the use of the rinse water supply system. Hence, the following aspects are considered and environmentally weighed for the evaluation of the external sprayer cleaning devices:

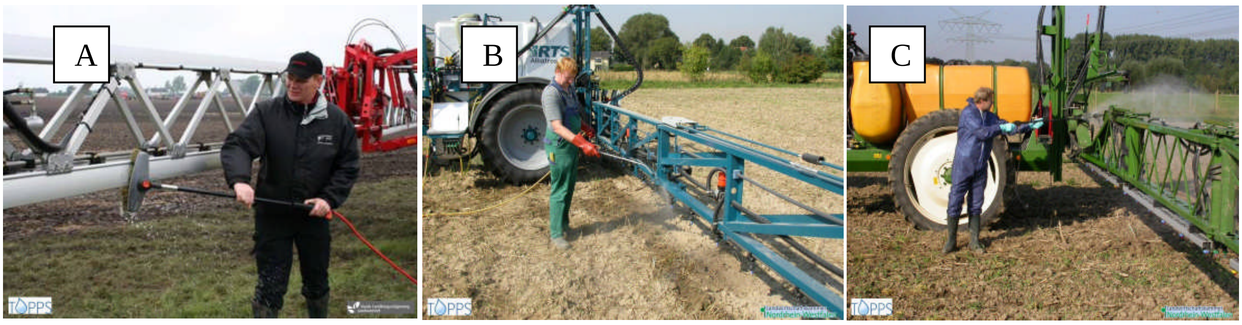


Figure 44: Different devices for external cleaning of sprayers
***A**: brush* ***B**: medium pressure lance* ***C**: high pressure lance*

- Type 60%
- Exposure to contamination 10%
- Supply system 30%

<u>Type</u>

Adequate cleaning levels with all types of cleaning devices may be achieved (Table 3) but, in practice, their use and acceptance by the operators must not be ignored. On the basis that the amount of time to clean the sprayer and the amount of water used are all comparable between systems then studies show that medium or high pressure spray guns find the best acceptance and therefore will lead to better results.

Table 3: Different devices for external cleaning of sprayers and their performance criteria (JKI, Germany)

Cleaning device	**Working pressure**	**Amount of clean water**	**Time consumption**	**Performance**
Lance	2,5 bar	70 l	30 min	68,2 %
Brush	3,0 bar	160 l	15 min	64,0 %
High pressure lance	15,0 bar	70 l	20 min	75,5 %

<u>Exposure to contamination</u>

External cleaning devices - supplied and fitted on the sprayer - should be kept protected from direct contamination whilst spraying (Figure 45). Even if the operator wears protective gloves, this requirement is a very important prerequisite for safe cleaning work.

Figure 45: Device for external cleaning protected behind a cover

Rinse water supply system

Basically two systems need to be recognised; those that deliver the rinse water by a separate pump (clean water direct) and those that deliver the rinse water using the main sprayer pump (clean water indirect). Internal rinsing must be carefully completed before external cleaning when using the main pump of the sprayer to deliver the rinse water. A failure to do this properly could result in undiluted residual spray liquid being externally applied at the beginning of the cleaning procedure. For example, if the main spray tank is not completely emptied when the main pump is used with these indirect systems, then it may not be possible to clean the external surfaces of the sprayer, (Figure 46).

Figure 46: External cleaning can be carried out more safely when a separate pump - to the main pump – is used.

6.2.2.2 Rinse water tank capacity – *TECHNOLOGY*

Rinse water tank capacities must be adequate to cope with – what will likely to be – both internal and external in-field cleaning demands. External cleaning demands for water may be less for some sprayers such as traditional orchard air-blast machines as they are without booms and their tank sizes and shapes may be easier and quicker to clean. However, it is possible every external surface of an orchard sprayer and its prime mover may need to be cleaned and this may need to be considered too. Field crop sprayers with their – often heavily contaminated - booms present large areas of multidirectional external surfaces where quick effective cleaning may be more difficult. The evaluation therefore weights these apparent differences.

6.3 Filling of sprayer - *EOS RISK AREA*

The loading of sprayers is a key activity and includes many tasks such as preparing the mixture of pesticides, the filling of the sprayer with water, cleaning and storing of discharged containers; tasks that are often done at speed yet all must not risk spills, splash, overflow or leaks. However, often where PPP are used very intensively, this filling stage – which may have been made in the farmyard - is estimated to be a significant point source for pollution. Increasing awareness of the needs to lessen these risks has prompted many technical improvements to the farm infrastructure and sprayer design.

The list of problems and their severity rates [%] identify the greater risk areas; the highest risk mitigation potential can be realized by the safe and effective introduction of PPP into the sprayer tank without spilling the undiluted product, and the filling of water without overflow of spray liquid. Technology [such as Closed Transfer Systems and metering devices] that avoids the need to measure out and pour PPP into hoppers and / or tanks directly may, therefore, also reduce the risk of point sources (Figure 47).

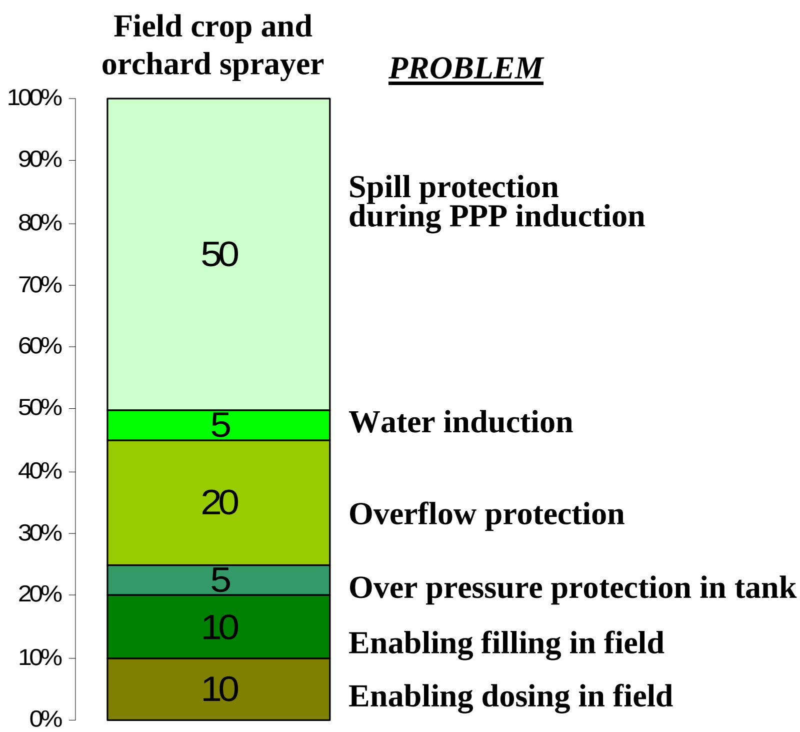


Figure 47: Problems related to the EOS risk area filling and their weights (%) for field crop and orchard sprayers

6.3.1 Spill protection during PPP induction – *PROBLEM*

The greatest risk of point source pollution when filling the sprayer is likely to arise from spilling undiluted PPP during its preparation as a premix or when being loaded into the sprayer. At this stage of sprayer use, any small spill or splash will greatly increase risks of actives reaching surface and / or ground water. Spilling risks are especially severe if the filling is done on impervious surfaces such as concrete without precautionary measures. Spill protection measures are therefore important and rated in the EOS model as high as 50% in the whole filling process (Figure 48).

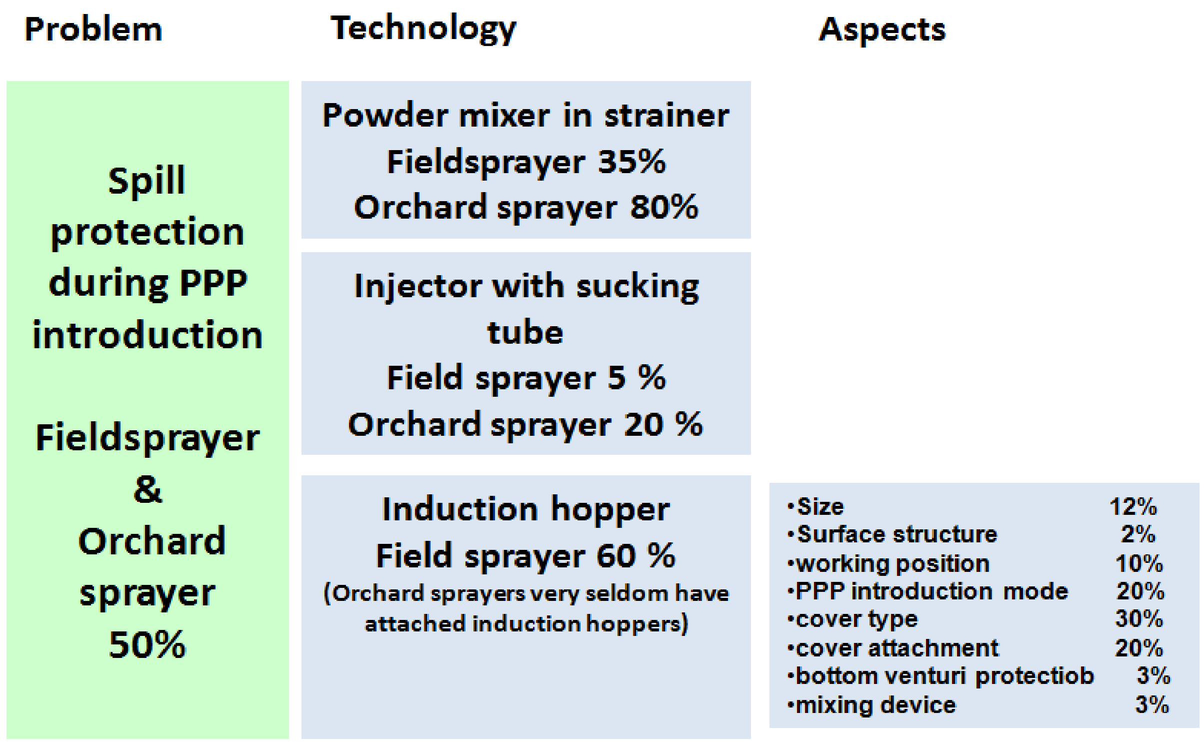


Figure 48: Evaluation structure, the weights of technology and the aspects relevant to spill protection during PPP loading

The use of appropriate means to limit spills are expressed by the standard EN/ISO 4254-6:2009 (Agricultural machinery - Safety - Sprayers and liquid fertilizer distributors).

Standard EN ISO 4254-6

To limit the risk of exposure to chemicals during filling/cleaning operations:

- *a chemical induction bowl or equally effective device shall be provided with the sprayer;*
- *alternatively, the filling hole of the spray tank shall be so positioned that the height from the ground or platform is not more than 1 300 mm, with the horizontal reach between the rim of the hole and the outer edge of any part of the sprayer which could hinder the operator being not be more than 300 mm at the operator filling position.*

EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors

Manufacturers offer diverse spill protection technologies; from low-tech catchment trays, pools and spill containment kits to metering pumps and advanced induction hoppers.

6.3.1.1 Powder mixer in strainer – *TECHNOLOGY*

Smaller field crop sprayers and many orchard sprayers – whose main filling hole is accessible from ground level – may not have induction hoppers fitted but will have modified filter basket strainers fitted in the filling hole of the tank (Figure 49]. These modified strainers permit most PPP formulations, especially liquids, powders and dry granules, to be directly introduced onto the strainer mesh and washed into the tank with water sprinkled by the mixer nozzle. The device is compact, entirely embedded in the sprayer tank and minimizes the problem of its cleaning. However some powder formulations that are not easily dissolved by water, require to be premixed in a bucket before being loaded through the strainer. Products applied at high dose rates that may require the introduction of large quantities of powder, may also not be effectively and/or safely mixed within the strainer.
The process of preparing a premix is always associated with the risk of spillage for it introduces an intermediate high risk task with the operator often mixing product in a bucket on the ground.
Any filling process that demands the operator to carry PPP onto the sprayer and/or raise containers above chest height increases risks greatly and must be avoided.
Powder mixers may also have PPP container cleaners fitted. The nozzle of these PPP container cleaner may be integrated with the mixer in the same strainer or it may constitute a separate device in a separate strainer (Figure 50). Integrated PPP container cleaners have the advantage that the container or measuring cylinder/jug can be cleaned directly after they have discharged their contents over the mesh.

Figure 49: Powder mixer in the strainer

Figure 50: Powder mixer integrated with container cleaner

6.3.1.2 Injector with suction tube - *TECHNOLOGY*

Orchard sprayers or small field crop sprayers can be equipped with an injection system that uses pressurized liquid connected to a hose whose opening can induce liquids, powders and slurries of PPP into the main tank (Figure 51). The injector is activated by opening the flow of pressurized liquid to create a vacuum in the suction tube such that the liquid or powder product is induced through the pipe and hose into the tank (Figure 52). Injectors are assembled either on the top of the tank or on the tank lid. The latter solution is preferred because in this case the product is directed through the strainer; a process that prevents any not completely dissolved product or other particles being accidentally added into the tank. The suction tube and its connecting hose, have contact with undiluted product so do need very careful internal and external cleaning. Injectors are believed to offer limited spillage protection.

Figure 51: Injector for inducing the PPPs from the container to the sprayer tank

Figure 52: The suction tube of an injector for inducing PPP into the tank

6.3.1.3 **Induction hopper** - *TECHNOLOGY*

Induction hoppers are likely to be the most effective technology currently available to minimize spills of PPP at the crucial loading stage. Hoppers are externally attached to the sprayer and have a tank [bowl/hopper] used to contain and/or measure the volumes of product to be loaded and, when needed, prepare the PPP premix. An injector [using suction from a venturi nozzle] transfers the PPP into the spray tank (Figure 53].
Induction hoppers are now available on most field crop sprayers and are located at a height that enables the convenient and safe introduction of PPP into the main tank by the operator standing on the ground. The hopper may be equipped with a cleaning system, a container cleaning nozzle and can be used with all PPP formulations.
The induction hopper may be a relatively complex device, be offered in different versions, may come with a variety of extra equipment, and be at a diverse levels of technical advancement, but have benefited from almost a universal acceptance within the EU. Following aspects have been considered and weighted in the EOS evaluation concept.

- size 12%
- surface structure 2%
- working position 10%
- PPP introduction mode 20%
- cover type 30%
- cover attachment 20%
- bottom venturi protection 3%
- mixing device 3%

Figure 53: Induction hopper on sprayer

Size

The size of induction hopper should readily permit the safe and effective introduction of PPPs and efficient cleaning of discharged containers. Size and design are important; the opening area in which PPPs are to be poured must be adequate enough to avoid splashing or spillage whilst its size must cope with the intended volumes – and rates of discharge – that they are to meet. Hoppers that are too small may also prevent bigger containers from being safely and efficiently rinsed by the cleaning nozzle that is integrated within the hopper. The general requirements for the opening of the hopper's tank are included in the standard ISO 21278-2:2008 (Equipment for crop protection. Induction hoppers - Part 2: General requirements and performance limits).

Standard ISO 21278-2

The opening size of the induction hopper shall be designed to allow:
- the filling of chemical products without splashing,
and
- the internal cleaning of cans of volumes up to at least 10 l (as specified in ISO 21278-1 clause 6.8.2).

ISO 21278-2:2008 Equipment for crop protection. induction hoppers. Part 2: General requirements and performance limits

Surface structure

Induction hoppers are usually made of polymers such as polyethylene, polyester or fibreglass but sometimes stainless steel too. All materials can differ in their smoothness of the surface and the ability of a PPP to be retained. Smoother surfaces and steeper side walls are some aspects that may prevent PPP from adhering to or accumulating on the hoppers internal surfaces; features that allow for easier and more effective cleaning.

Working position

The working position of the hopper should ensure its safe and easy operation; a need critical to the avoidance of any splash or spillage. These needs are met when the upper filling edge of the hopper's tank is below the waist of the operator - standing on the ground - next to the device. High-clearance trailed [or self propelled] sprayers may require the hopper to be lowered down to this working height then – after loading – to be raised up on folding systems such that the sprayer can work safely in the field (Figure 54).

Figure 54: Induction hopper assembled on a folding system for lowering to the convenient working position

Loading PPP into hoppers

Figure 55: Antispill opening on the cover of induction hopper for safe introduction of PPPs

The manner in which PPP are loaded into hoppers may also influence the scale of any risks. The most common procedure is to pour the product into the hopper's tank with the cover removed or hinged up and away. However, liquid products may be introduced with a still lower risk of spillage through an antispill opening located at the top of the hopper's cover (Figure 55). Such systems are mostly combined with container rinsing nozzles to clean the containers.

The loading of high volumes of liquid PPPs may use a separate 'Closed Transfer System' (Figure 56). The sprayers offering this loading option have a special, hermetic standardized coupling for the sealed attachment of the hose to be connected with the container to thereby enable the transfer of the liquid PPP. Whilst the risk of spillage is eliminated, in contrast, unless flow meters are used, no precise dosing of PPP may be possible and cleaning of the system may be difficult.

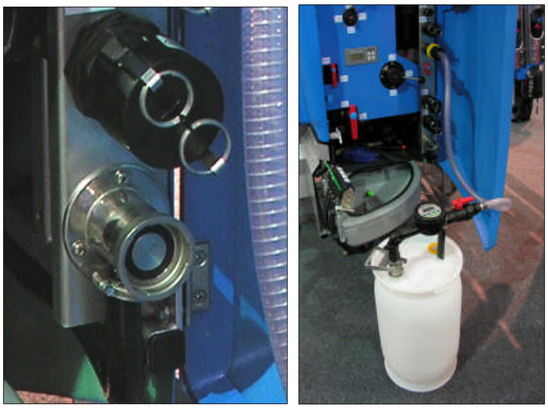


Figure 56: Coupling and container with hose for closed introduction of PPPs

Cover type

The cover of the hopper prevents PPP from being splashed out when they are being loaded into the hopper through the antispill opening and during the cleaning of the hopper's bowl with a rinsing nozzle. Additionally, the cover also protects the hopper from dirt and other debris entering as the sprayer moves in the field or on the road. The primary function of the cover requires that when in place it should be capable of being shut tight (standard ISO: 21278-2:2008 Equipment for crop protection - Induction hoppers - Part 2: General requirements and performance limits).

Standard ISO 21278-2

The cover shall be equipped with a closing system able to hold the cover shut tightly when necessary.

ISO 21278-2:2008 Equipment for crop protection. Induction hoppers. Part 2: General requirements and performance limits

Hopper cover profiles with a collar that fits inside the hopper's bowl, are preferred (Figure 57). Such collar types ensure that the premix or rinsate deposited on the inner surface of the cover is retained and drips back inside the hopper. When there is no collar, or when the collar is outside the bowl, there is a risk of releasing premix or rinsate to the outside the hopper and/or to spill on the ground (Figure 58).

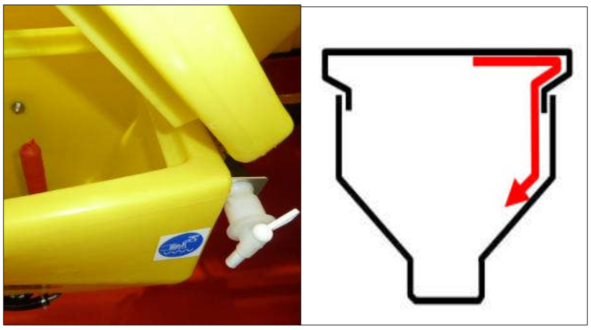


Figure 57: Induction hopper's cover with a collar inside the bowl

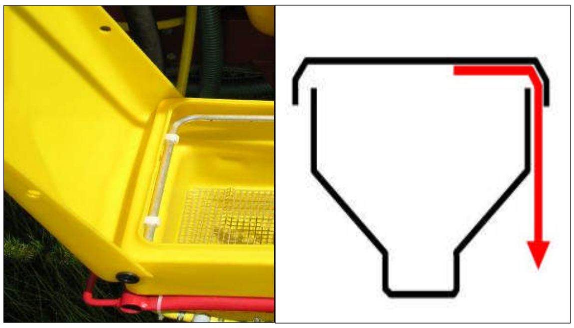


Figure 58: Induction hopper's cover with a collar outside the bowl

<u>Cover attachment</u>

According to the standard ISO 21278-2: 2008 (Equipment for crop protection. Induction hoppers. Part 2: General requirements and performance limits) the cover of the induction hopper should be attached to the induction hopper to avoid ground contamination; a risk for both point source pollution and of getting dirt or dust from the ground into the sprayer.

<u>Standard ISO 21278-2</u>

The cover shall be attached either to the induction hopper or to the sprayer, so that the cover may not come into contact with the ground.

ISO 21278-2:2008 Equipment for crop protection. Induction hoppers. Part 2: General requirements and performance limits

Lowest risks are achieved when the cover is simply hinged back (Figure 59). Loose attachment by a chain, string or elastic (Figure 60) usually makes the cover hang or rest in a vertical position, outside the bowl, and hence may permit contaminating liquid deposits from the inner surface of the cover to drip on the ground.

Figure 59: Induction hopper's cover attached by hinges eliminates the risk of spillage

Figure 60: The contaminated liquid may drip from the induction hopper's cover attached loosely by string or chain

Venturi nozzle protection

The venturi nozzle of the injection system that transfers undiluted or premixed PPP from the induction hopper to the sprayer's tank, as well as the hoses of the transfer system, have to be protected from being clogged by foreign bodies bigger than 20 mm (Standard ISO 21278-2: 2008 Equipment for crop protection. Induction hoppers. Part 2: General requirements and performance limits).

Filters, gauzes or mesh with a maximum mesh size of 20 mm (Figure 61) or other element are located at the bottom of the hopper to prevent large objects from getting into the injector system.

Figure 61: Gauze in the base of the induction hopper to protect the venturi nozzle

Standard ISO 21278-2

The outlet for the mixed solution shall not be so large as to allow a ball of 20 mm diameter to pass through it.

ISO 21278-2:2008 Equipment for crop protection. Induction hoppers. Part 2: General requirements and performance limits

Mixing devices

Powder- or water dispersible granular PPP - introduced by the induction hopper may need careful and thorough mixing with water before the hopper can transfer the product to the sprayer's tank. This may be done with a hand operated jet lance (Figure 62-A) or a side- or lower nozzle swirling the premix with a vortex movement (Figure 62-B,C) or with an agitation nozzle at the bottom of the bowl (Figure 62-D). The agitation- and lower vortex nozzles effectively mix the products without introducing air into the premix to, thereby, minimize the problem of foaming.

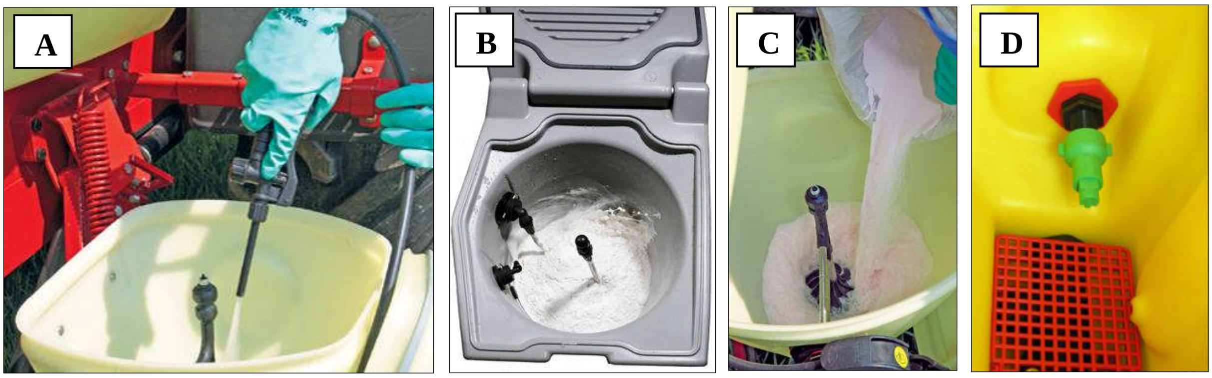


Figure 62: Mixing the PPP with water in the induction hopper:
***A** – hand operated jet-lance;* ***B** – side vortex nozzle;*
***C** - bottom vortex nozzle;* ***D** - agitation nozzle*

The side vortex nozzle allows the highest intensity of mixing to be gained but, because of air introduction into the premix, the mixing of some products may cause excessive foaming. The nozzles described above allow premixing at the same time as the product is being introduced into the bowl; an activity not always possible when mixing is done with the hand operated jet-lance. Mixing of powders, especially with jet-lance and vortex nozzles also prevent the products from being retained on the inner surface of the bowl to make the cleaning of hopper much easier and more efficient.

6.3.2 Water induction – *PROBLEM*

Filling the sprayer with water is not associated with any high risk of environmental pollution. The severity of this problem in the EOS model has, therefore, only been rated at 5%. However, splashing of water that gets in contact with some internal parts of the tank, like a strainer, during filling through the filing hole may indeed have an environmental impact. Similarly, backflow of liquid from the tank to the water source and contact of contaminated filling hose with the water source when using a filling device are also recognised risks.

Problem	**Technology**	**Aspects**
Water induction **Fieldsprayer & Orchard sprayer 5%**	**Filling hole** **Field & Orchard sprayer** **20%**	Diameter 40% Position 30% Depth of strainer 30%
	Filling device **Field & Orchard sprayer** **80 %**	Type 80% Exposure to contamunation 20%

Figure 63: Evaluation structure and weights of technology and aspects relevant for the water induction

6.3.2.1 **Filling hole** – *TECHNOLOGY*

Design and location of the filling hole determines the risk and incidence of water splash. The environmental evaluation of the filling hole is made, therefore, taking into account three aspects and their importance is expressed in percent:

- diameter 40%
- position 30%
- strainer depth 30%

Filling hole diameter ***(Standards* EN 12761-2: 2001 AND EN 12761-3: 2001*)***

The size of the sprayer – and the area it is used on – may influence the preferred capacity of its water supply system. The sprayers with small and medium tanks (up to 600 l) are typically filled with a low capacity water hose so the diameter of opening is not a crucial factor determining filling safety and efficiency. The bigger tanks (>600 l) may be filled with high capacity systems so the diameter of the filling hole should be large enough to facilitate an intensive flow of water with a minimum risk of splashing (figure 64). The minimum required diameters of the filling holes are determined in the standard ISO 9357: 1990 (Equipment for crop protection. Agricultural sprayers. Tank nominal volume and filling hole diameter).

Figure 64: Filling hole diameter should be large enough to facilitate an intensive flow of water with a minimum risk of splashing

__Standard EN 12761-2__
__Standard EN 12761-3__
The diameter of the filling hole should be in accordance with standard ***ISO 9357***
__Standard ISO 9357__
The filling hole minimum diameter shall correspond to the nominal tank volume as below:

Nominal tank capacity C [L]	*Min filling hole diameter [mm]*
5 < C < 100	*100*
C = 100 *C = 150*	*150*
C = 200 *C = 300* *C = 400* *C = 500* *C = 600*	*200*
C = 700 *C = 800* *C = 900* *C = 1000* *C > 1000*	*300*

ISO 9357:1990 Equipment for crop protection. Agricultural sprayers. Tank nominal volume and filling hole diameter
EN 12761-2: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers
EN 12761-3: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 3: Air-assisted sprayers

__Filling hole position__

The position of the filling hole on the sprayer tank should ensure easy access by the operator standing securely at or on the intended location for loading PPP. Easy access minimizes risk of the PPP spillage when the product is introduced through the filling hole and it facilitates filling the sprayer with water without splashing. For larger tanks, accessibility is ensured by locating the filling hole asymmetrically, closer to the operating platform (Figure 65). The filling hole position is determined by standard ISO 4254-6: 2009 (Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors).

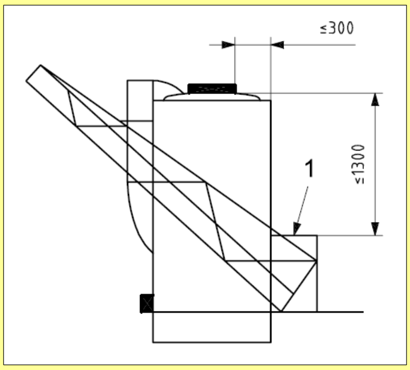
Figure 65: Asymmetrically located filling hole makes it easily accessible by the operator

Standard EN ISO 4254-6

To limit the risk of exposure to chemicals during filling/cleaning operations:

- *a chemical induction bowl or equally effective device shall be provided with the sprayer;*

- *alternatively, the filling hole of the spray tank shall be so positioned that the height from the ground or platform is not more than 1 300 mm, with the horizontal reach between the rim of the hole and the outer edge of any part of the sprayer which could hinder the operator being not be more than 300 mm at the operator filling position (see Figure right)*



EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors

Strainer depth

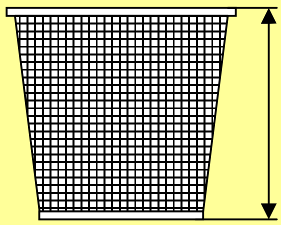
The diameter of the filling hole determines the diameter of the strainer. However, it is the strainer depth that may mainly influence both safe PPP introduction and tank filling with water; deeper strainers may lower the risk of splashing when the tank is filled with a high capacity water supply system (Figure 66). Required depth of strainer is, therefore, dependent on the tank size and that requirement is stated by the standards EN 12761-2: 2001 and EN 12761-3: 2001 (Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers. Part 3: Air-assisted sprayers). However, in some situations, deep strainers can hinder effective internal cleaning of the tank for they may be a barrier to the rinse water reaching all areas of the tank. Such situations should be avoided and care taken to optimise the design of the cleaning system.

Figure 66: Deep strainer facilitates safe and efficient filling of the tank with water with no risk of splashing

Standards EN 12761-2 and EN 12761-3

The minimum depth of the strainer shall correspond to the nominal tank volume as below:

Nominal tank capacity C [l]	***Min depth of strainer d [mm]***
C ≤ 150	***60***
150 < C ≤ 400	***100***
400 < C ≤ 600	***150***
C > 600	***250***



EN 12761-2: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers

EN 12761-3: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 3: Air-assisted sprayers

6.3.2.2 Filling device – *TECHNOLOGY*

Filling of sprayers using a dedicated filling device is a preferred alternative to the use of the main tank filling hole. These systems allows water from any source (pressurized or not pressurized) to be pumped [typically from a bowser] by the sprayer itself into the sprayer tank through the liquid system of the sprayer. This way of filling greatly reduces the risk of splashing water at the filling hole, is safe and convenient for the operator who does not need to climb on the working platform.

The filling device uses the sprayer pump and can work either on the suction- or on the pressure side of the liquid system. In either case, the suction hose of the device is, on one side, connected to the sprayer liquid system and, on the other, to the water source (Figure 67).

Increasingly, on larger sprayers especially, as the water is being transferred from the bowser, will the operator use this clean water [rather than the re-circulating spray solution] to operate his induction bowl and container rinsing facilities as the PPP is being loaded.

Figure 67: The filling device connected to the sprayer and water source

In order to protect the water source from being polluted, the filling device should be designed to ensure that no spray solution can be transferred back to the water source. This critical need must be considered with any technical solution on how the filling device / hose is protected from PPP contamination.

The environmental evaluation of the filling device and their % weights are given below:

- type of device 80%
- exposure to contamination 20%

<u>Type of device</u>

The filling device, or any sprayer connected to such a device, should be equipped with anti-backflow valve which protects the water source from being contaminated. Such requirement is stated in the standards EN 12761-2: 2001 and EN 12761-3: 2001 (Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers. Part 3: Air-assisted sprayers).

<u>Standard EN 12761-2</u>
<u>Standard EN 12761-3</u>

The filling device should be designed so that the liquid is prevented from the back-flow from the tank to the water supply system

EN 12761-2: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers

EN 12761-3: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 3: Air-assisted sprayers

Water contamination risks

Water sources must not be contaminated when using filling device; any part of the suction hose getting in contact with the water source must be clean. Avoid, for example, transporting the coiled hose on the sprayer in a position that is exposed to any spray or could make direct contact with PPP (Figure 68). Do keep the hose clean by, for example, a cover or shield when on the sprayer. The ideal solution is to have a dedicated cover or high capacity locker (Figure 69, 70) which is never used to transport PPPs or any other contaminated items.

Figure 68: Coiled hose of filling device exposed to contamination

Figure 69: The high capacity locker for the hose of filling device to protect it from contamination

Figure 70: The hose of filling device covered to protect it from contamination

6.3.3 Overflow protection – *PROBLEM*

Overflow of the tank mix, from the main spray tank at the time of sprayer filling, is considered the next most important risk [after spillage of undiluted PPP] for environmental contamination. The severity of this problem has been rated in the EOS evaluation model at 20%. (Figure 71). Overflowing mainly happens due to lack of attention, distraction or other carelessness, by the operator and or lack of measures or instruments to prevent spray mixture from overflowing. Technologies such as liquid level indicators, sensors or flow meters help the operator to monitor the volume of water being filled into the tank. These devices enable him to fill precisely with the required volume of water to form his intended spray solution. Spray tanks do have capacities in excess of those for which they are rated and this may help limit some instances of overfilling and be tolerant of smaller errors. In some instances, excessive foaming of some PPP are believed to have prompted an overflow sufficient enough to contaminate the working environment too.

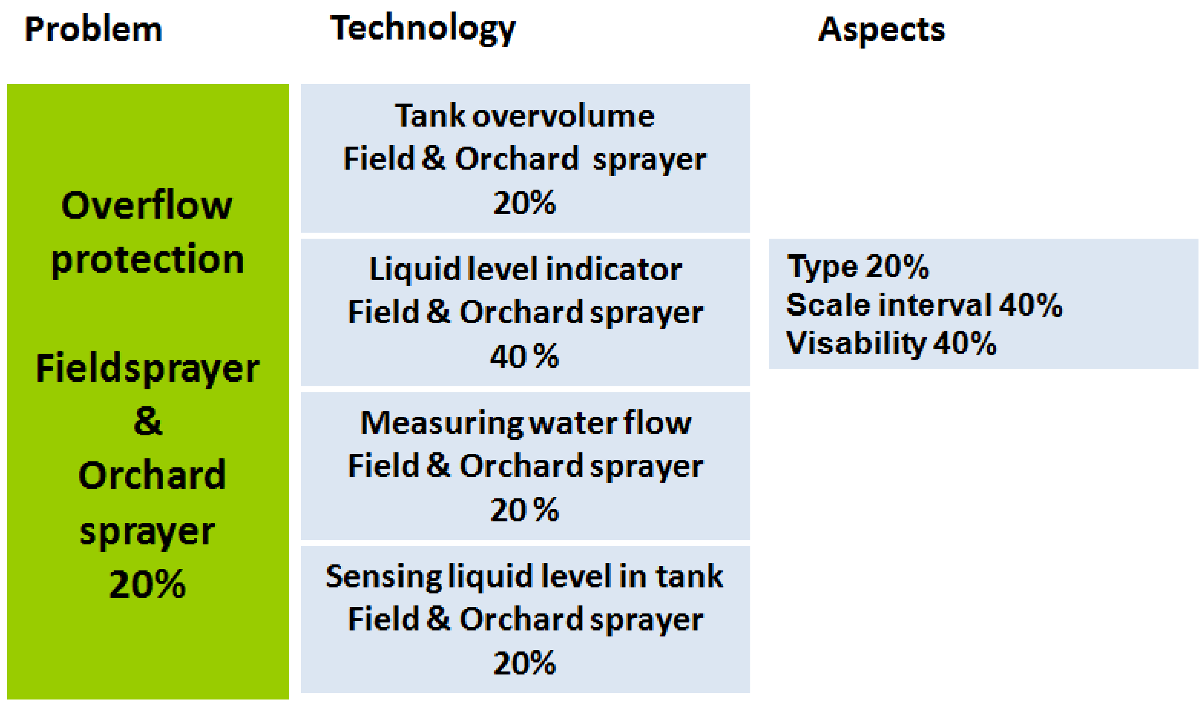


Figure 71: Evaluation structure and weights of technology and aspects relevant for overflow protection.

6.3.3.1 Tank excess capacity - *TECHNOLOGY*

The tank's excess capacity is that which is in excess of that for which the tank is rated [its nominal maximum volume] (Figure 72). Tank 'over volumes' help prevent the liquid from overflowing when the nominal volume of the tank is exceeded or foaming is a problem. The over-volume of spray tanks is required by the standard ISO 4254-6: 2009 (Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors). ISO requirements are for at least an additional 5% of the nominal tank volume but, to increase environmental safety of sprayers, a 10% over-volume is preferred.

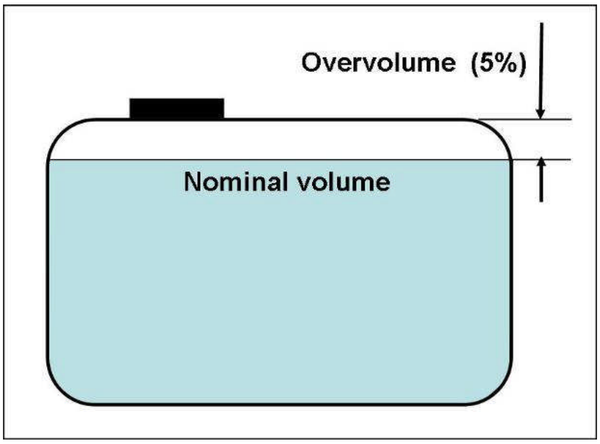


Figure 72: The total tank volume should exceed the nominal maximum volume by at least 5 %

Standard EN ISO 4254-6

The actual overall volume of the tank shall exceed the nominal volume by at least 5 %

EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors

6.3.3.2 Liquid level indicator – *TECHNOLOGY*

The risk of overflow is best reduced when the operator can precisely monitor the level of liquid during the filling of the tank with water. This monitoring is possible with an accurate and highly visible, easy to read indicator level mounted on – or part of - the sprayer. Flow meters may also be a very precise loading method, too. Research has shown that the scales [often moulded in or vertically mounted adjacent to the tank] on the sprayers, are not very precise so make the determining of exact volumes difficult. The requirement for such indicators are stated in the standard ISO 4254-6: 2009 (Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors).

> ***Standard EN ISO 4254-6***
>
> *The level of liquid shall be indicated to the operator during filling and emptying. The nominal volume of the tank shall be marked.*
>
> *EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors*

Liquid level indicator are evaluated from the environmental point of view, taking into account the three following aspects and their importance expressed in percent:

- type 20%
- scale interval 40%
- visibility 40%

Type

The level of liquid in the tank may be indicated in different ways. When the tank is made of a translucent material, the level of liquid can be seen directly in the tank (Figure 73). These measuring methods are likely to be not very precise and, additionally, after a period of time, the inner walls of the tank become less translucent and the scale not readable. Indeed, in certain light conditions, the level of liquid may not be seen even through the wall of a new tank. To ease seeing tank contents, a transparent tube is often vertically attached to the side of the tank. The level of liquid in the tank is then indicated in this tube (Figure 74) but, as it is filled with the spray solution, will get contaminated and will still lose some scale reading ability.

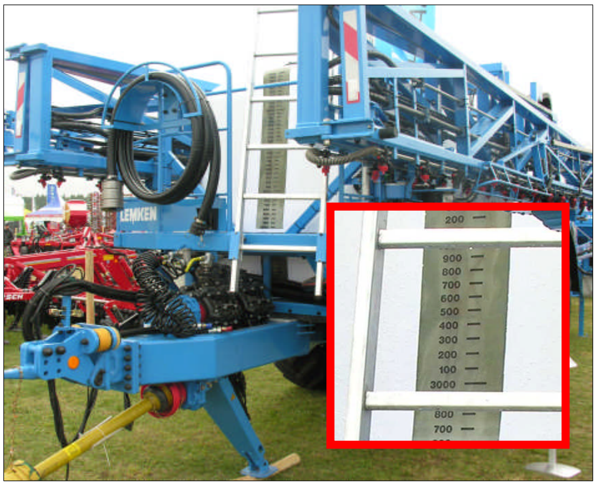


Figure 73: Direct liquid level indicator

Figure 74: Wet tube liquid level indicator

The level of liquid may also be identified indirectly by using a float located inside the tank and connected with a cord and indicator moving in a dry tube (Figure 75), or with a clock mechanism and needle on a rounded scale (Figure 76). The dry tube and float-and-clock indicators are easily read and, without direct contact with the spray mix, will retain that need, may need no cleaning and pose no threat of leakage in case of mechanical damage of the indicators.

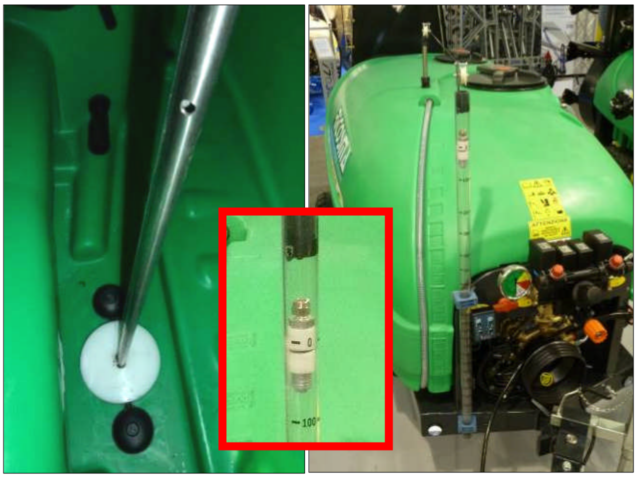


Figure 75: Float and dry tube liquid level indicator

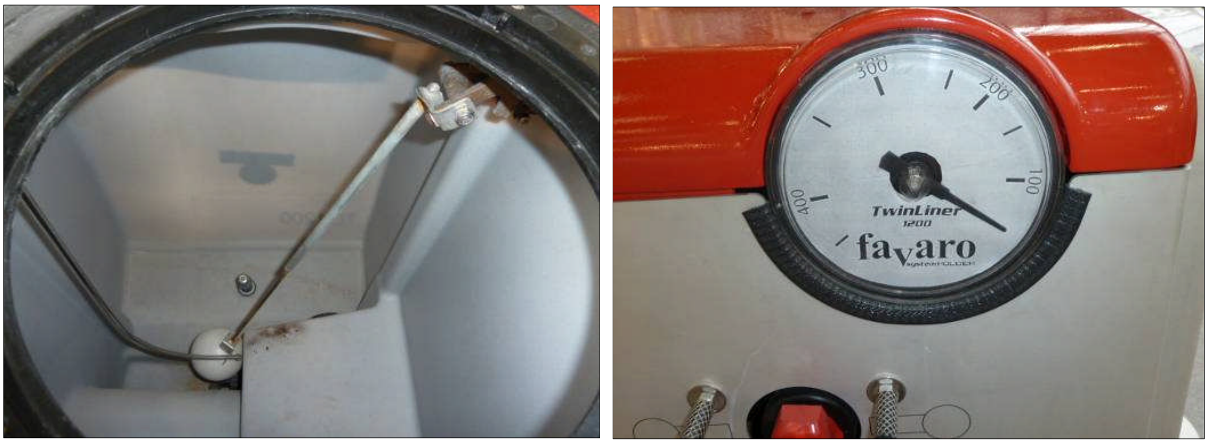


Figure 76: Float-and-clock liquid level indicator

Finally, the spray liquid level may be indicated by electronic level gauges that determine volumes, based on the measurement of static pressure of liquid, at the bottom of the tank. The pressure measured by the transducer of the gauge (Figure 77) is converted into the units of liquid volume in the tank. This value is usually displayed on the panel of the spray control unit in the tractor cab (Figure 78), during the spray application and remains always visible to the operator. However, the operator still needs to control the liquid level during filling so these electronic level gauges remain as a complementary indicator to another additional means.

Figure 77: Electronic level gauge

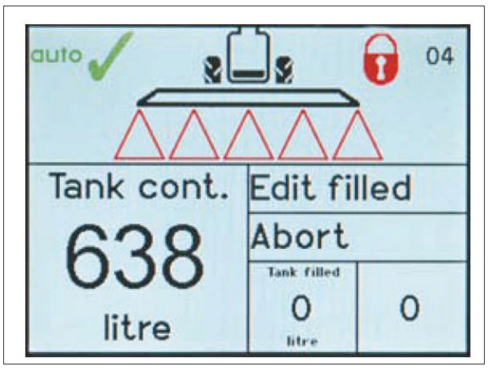


Figure 78: Tank content reading on the control unit display

Scale interval

The accuracy of the measurement of liquid volumes in the tank, depends also on the intervals used between the marks of the level indicator scale and the scales precision itself (Figure 79). If the scales are too narrow, the risk for imprecise measurements is high. The scale interval is stated by the standard ISO 9357: 1990 (Equipment for crop protection. Agricultural sprayers. Tank nominal volume and filling hole diameter).

Figure 79: Tank of nominal volume 2000 l with a liquid level indicator with scale interval

Standard EN 12761-2
Standard EN 12761-3

The indication of the tank contents should be in accordance with standard ***ISO 9357***

Standard ISO 9357

The contents gauge scale between marks shall correspond to the nominal tank volume as below:

Nominal tank capacity C [l]	*Contents gauge scale between two marks [l]*
1 *2* *3* *4* *5* *5 < C < 100*	*1*
C = 100 *C = 150*	*25*
C = 200 *C = 300* *C = 400* *C = 500* *C = 600*	*50*
C = 700 *C = 800* *C = 900* *C = 1000*	*50*
C > 1000	*100*

ISO 9357:1990 Equipment for crop protection. Agricultural sprayers. Tank nominal volume and filling hole diameter
EN 12761-2: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers

EN 12761-3: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 3: Air-assisted sprayers

The acceptable indicator tolerances are stated by the standards EN 12761-2: 2001 and EN 12761-3: 2001 (Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers. Part 3: Air-assisted sprayers).

<u>Standard EN 12761-2</u>
<u>Standard EN 12761-3</u>

The acceptable tolerances of the contents indicator are:
- *± 7,5 % for each graduation mark for volumes up to 20 % of the nominal tank volume;*
- *± 5 % for each graduation mark for volumes above 20 % of the nominal tank volume.*

The tolerances shall be measured with a maximum error on measurement of ± 1 % with the sprayer in a horizontal position.

EN 12761-2: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers

EN 12761-3: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 3: Air-assisted sprayers

Flow meters, which can exactly measure the water volume transferred to the spray tank, are a preferred technical option. Any imprecise measurement method, may lead not only to higher environmental risks as a consequence of over filling tanks or having excess spray liquid to be managed but, additionally, due to inaccurate water volumes being used, could effect the safety of the PPP use such as residue levels, efficacy.

<u>Visibility</u>

Operators have to see the indicator level from the filling position to monitor the level of spray liquid in the tank and to avoid its overflow during sprayer filling. In addition, he also needs to monitor the tank content during the spraying treatment too, in order to know the volume remaining as well as noting the sprayers correct performance. The indicator has to be clearly visible and readable both from the filling place and the tractor cab. This requirement is included in the standards EN 12761-2: 2001 and EN 12761-2: 2001 (Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers. Part 3: Air-assisted sprayers).

<u>Standard EN 12761-2</u>
<u>Standard EN 12761-3</u>

The liquid level indicator should always be well seen from the operator's seat and from the place from where the sprayer is filled

EN 12761-2: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 2: Field crop sprayers

EN 12761-3: 2001 Agricultural and forestry machinery. Sprayers and liquid fertilizer distributors. Environmental protection. Part 3: Air-assisted sprayers

6.3.3.3 Measuring water flow - *TECHNOLOGY*

The measurement of water flow during the filling process is used to determine the required and/or total volume that is transferred into the sprayer's main tank. The operator monitoring the flow can manually stop filling at the right moment ensuring the exactly required water volume is used and risks, such as overflow of tank, are avoided. Programmable flow meters (Figure 80) can be set to shut-off a valve automatically to stop loading when the correct amount is filled and to avoid overflow.

6.3.3.4 Sensing level of liquid - *TECHNOLOGY*

Level sensors are electronic instruments that identify when a preset level of spray liquid in the tank is reached to either trigger an alarm to alert the operator or automatically shut-off the valve at the water supply hose. Thus, its primary function is to sense the water [spray solution] level rather than measure the spray liquid volume. These sensors are mounted either internally or externally on the sprayer tank (Figure 81).

Figure 80: Programmable flow meter to control the volume of water filled to the sprayer tank

Figure 81: The liquid level sensor on the sprayer tank

6.3.4. Over pressure protection in tank –*PROBLEM*

Air in the tank is replaced with water when being filled but, conversely, needs to allow air in when spraying. If the tank is air- tight, pressures may quickly rise [or fall] to an extent that some means must exist to prevent damage to that tank. Devices are needed to avoid both over and under pressurising the tank to avoid damage and ensure its correct operation. Therefore, a pressure compensation device is required by standard ISO 4254-6.

<u>Standard EN ISO 4254-6, clause 5.4.2</u>

A pressure-compensation device shall be fitted on tanks that are not designed to be put under pressure, in order to keep them at atmospheric pressure when emptying and filling.

EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors

6.3.4.1 Pressure compensation in tank – *TECHNOLOGY*

Pressure compensation in spray tanks is ensured with a device that lets air in and out of the tank without risk of spray liquid leakage or the ingress of dirt. The most common device used is an **air valve** placed at the top of tank or within the tank lid (Figure 82).

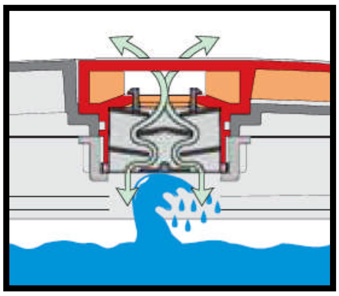


Figure 82: Air valve for pressure compensation in tank

6.3.5 Enabling filling in field - *PROBLEM*

Filling [loading] sprayers in the field may be a better and low cost, alternative, investment to filling at the farm. Using the correct equipment, techniques and choice of site in the field may reduce the risk of water pollution from that used at the farmyard where more expensive precautionary measures for filling may not be available. Currently, field filling is mainly a practice where fields are located at a distance from the farm and by spraying contractors, too. Components that facilitate the safe and effective filling of sprayers in the field include the induction hopper with a container cleaner, additional tank for rinsing water, the filling device as well as a means for cleaning PPP measuring utensils too. All these technologies are described in the previous sections of this brochure and they are key elements of the EOS model. However, in order to minimize the risk of environmental pollution associated with filling of sprayers in the field - and to make the process safe and convenient for the operator - the sprayer should be equipped for the safe transportation of PPPs and water in compliance with local regulations (Figure 83).

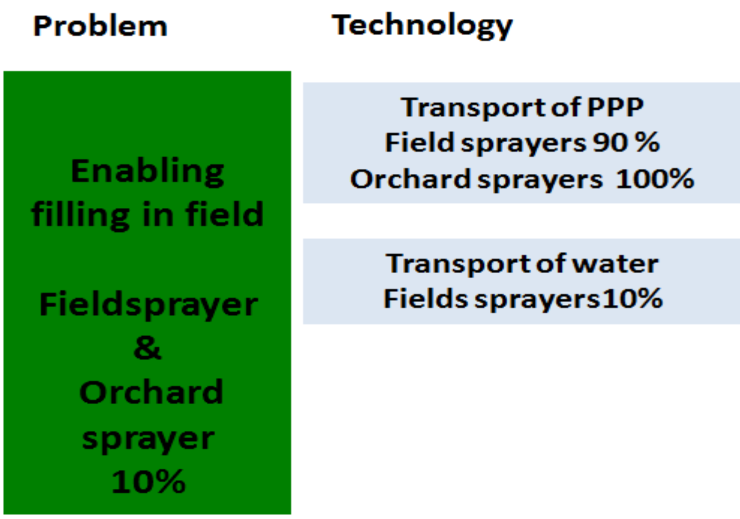


Figure 83: Evaluation structure and weights of technology for enabling filling in field

6.3.5.1 Transport of PPPs – *TECHNOLOGY*

PPPs must not be transported in the tractor cabin nor as an unsecured load on the sprayer. Risks of pollution in transit from accidental damage of the PPP packaging must be avoided with the use of a dedicated locker capable of retaining spills. The locker should be closable and preferably lockable (Figure 84) to prevent PPPs from being misused or accessible to unauthorized persons. Location of these lockers is usually best close to the induction hopper and/or the position where the operator fills the sprayer.

Figure 84: The lockable PPP locker retaining spills

6.3.5.2 Transport of water - *TECHNOLOGY*

Normally, water is transported in the sprayers main tank to the field to be sprayed with PPP loading being done at that planned treatment site. However, it is also possible to transport larger supplies of water in a separate trailed tank towed behind the sprayer; an operational benefit that saves time [especially with larger spraying activities] and reduces the risk of polluting the farmyard and the access tracks/roads with a contaminated sprayer when refilling the tank (Figure 85). A safe and appropriate hitch is needed at the rear of the sprayer for towing (Figure 86).

Local regulations on road traffic and transportation requirements must be checked as the towing of trailed vehicles behind the sprayer may not always be legally permitted.

Figure 85: The trailer tank to transport water to the field

Figure 86: The hitch to tow the trailer tank behind the sprayer

6.3.6 Enabling PPP dosing in field - *PROBLEM*

Many PPP are supplied in containers sizes and packs that are appropriate to the advised dose to be applied over a known area such as a hectare. In these instances, then the whole container content may be loaded with out further measurements. However, when part loads are needed or different doses or spray solution concentrations are to be applied then there may be a need for exact measurements of liquid- or dry - PPPs with the use of dedicated measuring utensils and/or instruments.
Loading sprayers with PPP in the field may have environmental benefits over the same task made near farm buildings; field loading sites can be regularly changed and there are less risks from transporting diluted PPP solutions on roads and tracks. Filling operations carried out on farmyards are a considerable risk of point source pollution if respective measures are not available or executed. Sprayer loading of PPP in the field of use is an accepted practice providing measuring equipment is available (Figure 87).

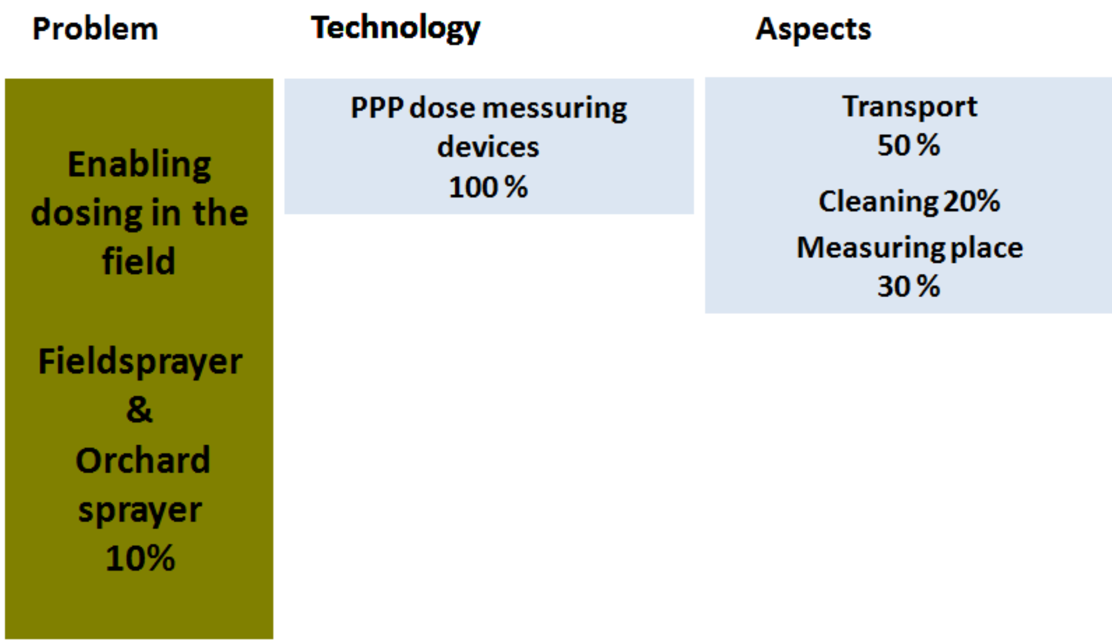


Figure 87: Evaluation structure and weights of technology and aspects for enabling dosing of PPP in the field

6.3.6.1 PPP measuring devices - *TECHNOLOGY*

The measuring devices to be used, to ensure the required dose is applied, will need to be transported with, or on, the sprayer to the loading site in the field. Measuring undiluted PPP is closely linked to a high risk of point source pollution so must be made – with extreme care - in an area of low environmental risk. Measuring utensils (e.g. scoop and jar) must also be cleaned – quickly and effectively - after use; a task that may demand pre-planned facilities to be available and ready for use. The level of adaptability of the sprayer for PPP measurements in the field should be evaluated whilst taking into account the three above mentioned aspects - and their environmental importance – to be expressed in percent:

- transport 50 %
- measuring place 30%
- cleaning 20 %

<u>Transport</u>

PPP measuring equipment such as scoops, jars and weighing devices should be transported in a locker capable of retaining spills. This locker should be located close to the measuring area and also the place where the PPP is to be loaded or mixed Figure 88).

Figure 88: The dose measuring devices should be transported in a locker able to retain spills

6.4 Remnant management

EOS - RISK AREA

Any remaining spray solution in the sprayer - at the end of the application - has to be safely and effectively managed in a manner that avoid risks of environmental contamination. It is most important to reduce as much as possible the volume of any remnants through precise calibration of the sprayer and its subsequent loading and use. However, those activities that enable the full use of the whole volume of spray mixture in the main tank are only made possible through an adequate sprayer design too. Complete emptying of the sprayer – through spraying out all the prepared spray solution in its intended manner– is only possible with features such as effective main tank sumps and pumping systems.

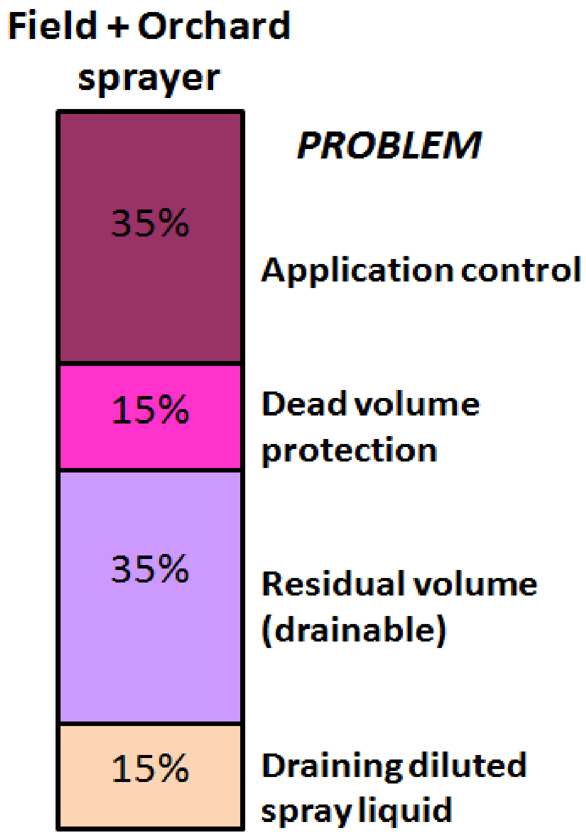


Figure: 89: Problems related to the EOS risk area remnant management and their weights (%) for field crop and orchard sprayers

Minimizing the residual (drainable) volume of spray liquid that is retained in the sprayer and the effective management of the application itself have the most important weights in terms of mitigation potential. Minimising the dead volume protection and maximising the scope to drain diluted spray liquid must also be achieved to facilitate the correct management of spray remnants (Figure 89).

6.4.1 Application control – *PROBLEM*

Preventative measures are important to avoid any excess of spray liquid in the sprayer's tank remaining after the full application process in the field has been completed. A key aspect that determines the correct spray liquid rate per area unit is used is, therefore, the control of the application itself. Application control is given a 35% weight in the EOS model and it includes three different technologies through which the volume rate per hectare can be monitored and kept constant at the required level: liquid flow adjustment, forward speed monitoring and ON/OFF valves enabling to switch on/off the nozzles (Figure 90).

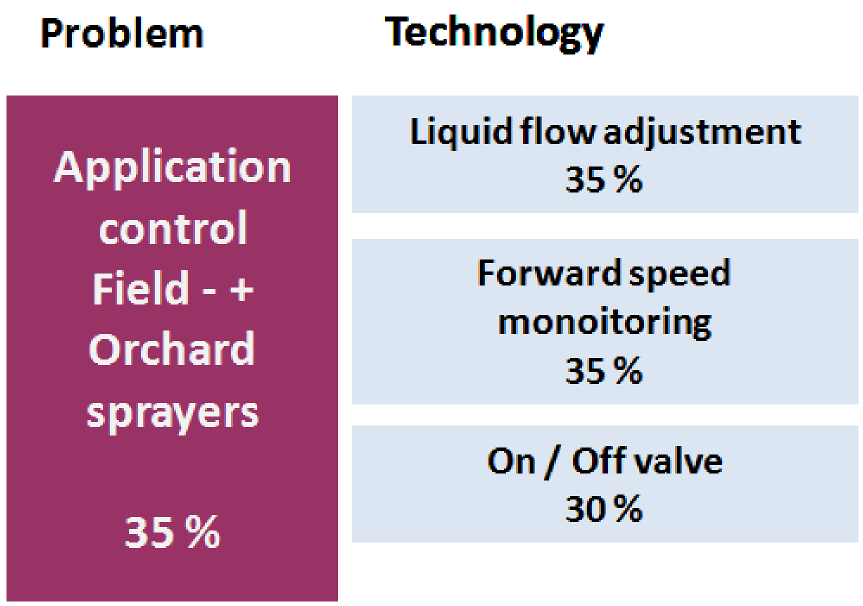


Figure 90: Evaluation structure and weights of technology for application control.

6.4 .1.1 Liquid flow adjustment - *TECHNOLOGY*

When the required volume application rate (Volume / time) is established, it is important that it is kept constant and that the exact amount of spray mixture needed is applied over the intended treatment zone; a critical need to ensuring a predicted dose of PPP is uniformly applied. Achieving a constant volume application rate depends essentially on two parameters: the liquid flow rate and the forward speed of the sprayer.

Flow rate control and adjustment can be gained with a **manual** system using a pressure regulator (Figure 91) or it can be **automatic** with systems such a Dose Proportional Adjustment system (DPA) (Figure 92) that adjust the sprayer flow rate according to the forward speed; the management of the pressure regulation being electronic and the forward speed being monitored by speed sensors. These DPA systems are commonly used on field crop sprayers (especially large trailed and self-propelled sprayers), while they are less common on orchard sprayers.

Figure 91: Manual pressure regulator

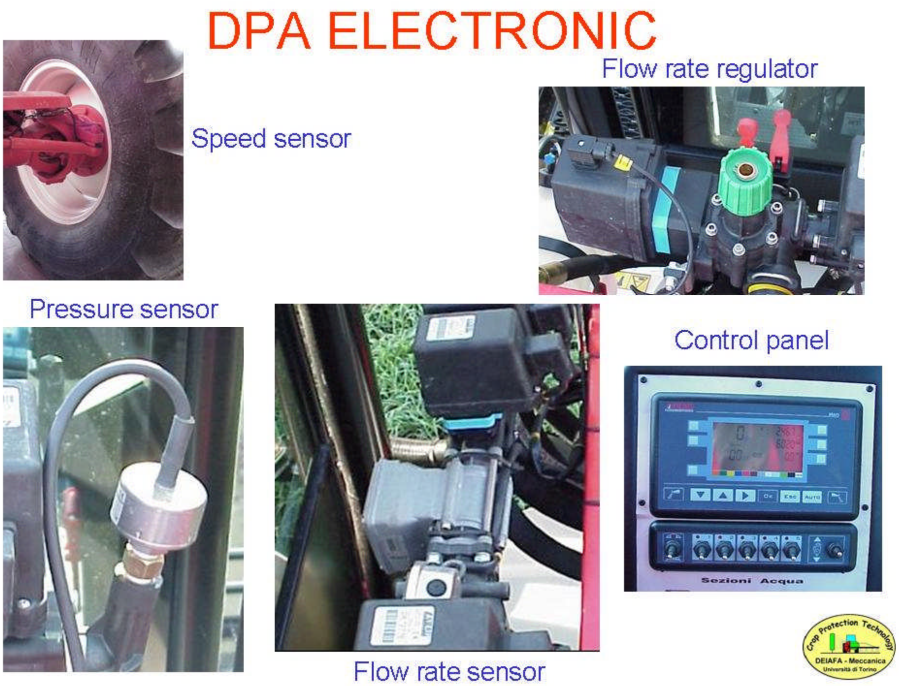


Figure 92: Components of a Dose Proportional Adjustment system.

6.4.1.2 Forward speed monitoring- *TECHNOLOGY*

Achieving and monitoring the required forward speed during spraying is essential to precise application; a key goal that is enabled with both direct and indirect systems. Most commonly used methods are based on the tractor speedometer, linked to the engine revolution speed (monitor land speed). Other systems are based on GPS or radar that can provide information about the sprayer forward speed by calculating the time needed to cover a measured distance. The most precise systems to monitor the sprayer forward speed are, today, the use of proximity or encoder sensors mounted close to the wheel of the sprayer (Figure 93).

Figure 93: Proximity sensor mounted on the sprayer wheel

6.4.1.3 ON/OFF valves- *TECHNOLOGY*

Full control of the spray application requires the ability to shut off the nozzles when the edge of the intended treatment area is reached; spraying being restarted again only when the spray nozzles are positioned over the area that is next to be treated. This operation of switching on and off the nozzles can be made manually with ON/OFF valves positioned on the sprayers, or with more easy-to-use electric valves that can be operated directly from the tractor cabin (Figure 94). The more sophisticated electronic valve systems - linked by GPS/GIS to precisely position the sprayer within the treatment zone – may achieve an automatic, very precise control of the spray application (see also 6.5.2.2) (Figure 95).

Figure 94: Electric ON/OFF valves operated from the tractor cabin.

Figure 95: Electronically controlled individual nozzle ON/OFF valve

6.4.2 Dead volume protection – *PROBLEM*

Any spray solution that is retained within the sprayer after use – and cannot be diluted with rinsing water during the subsequent cleaning process- is an environmental risk and must be minimised. This ‘dead’ volume [ISO 13440:1996 “Equipment for crop protection -Agricultural sprayers - Determination of the volume of total residual”, clause 2.3] is defined as that spray solution that “cannot flow back to the tank during normal operation of the sprayer”. In reality, most liquid that comprises ‘dead’ volumes are the spray solution remaining within [non re-circulating] delivery hoses between the pump and the nozzles.
Residual liquid in the main tank, which cannot be pumped out, is also important since complete drainage is not ensured. Appropriate devices that drain both filters and tank can achieve this goal. In EOS tables a 15% environmental weight is given to this problem (Figure 96).

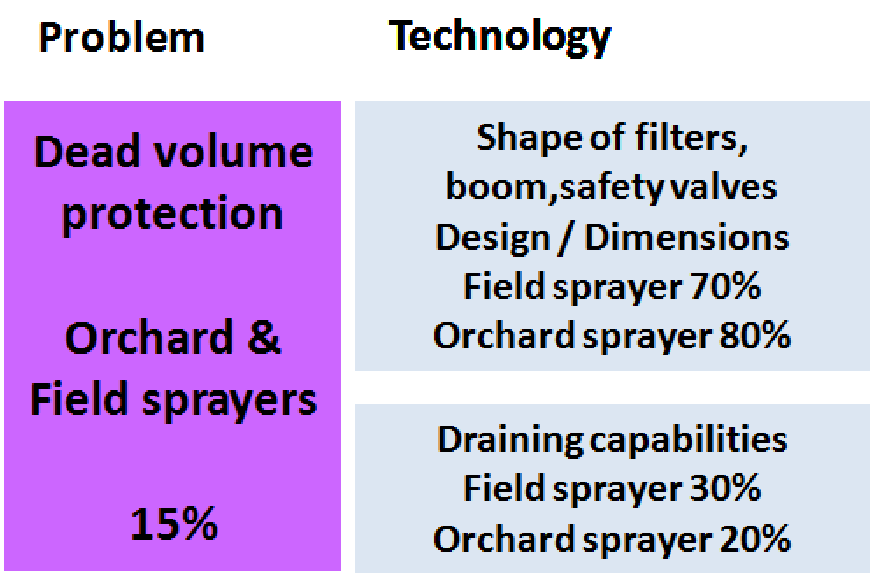


Figure 96: Evaluation structure and weights of technology related to the problem of “dead volume protection”

6.4.2.1 Filter / boom / safety valves – *TECHNOLOGY*

Flush valves can be installed in the sprayer circulation system to drain dead volumes in hoses (Figure 97). Flush valves should permit the safe collection of liquid contaminated with PPP.

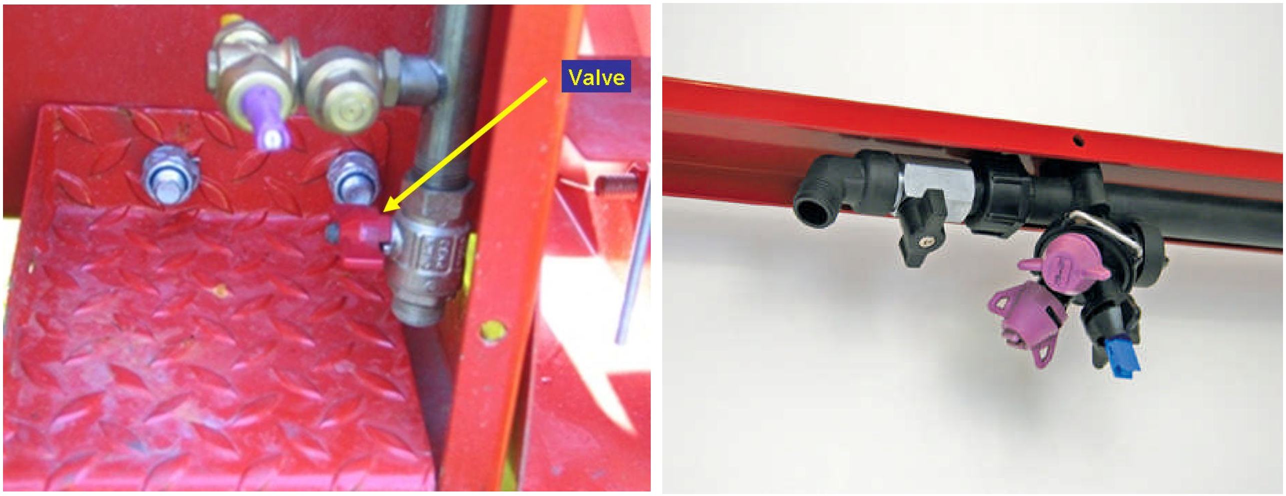


Figure 97: Flush valve to drain dead volume from spray supply hoses. (left orchard- right field crop sprayer)

6.4.3.2 Draining capability – *TECHNOLOGY*

> ***Standard EN ISO 4254-6***
>
> *An emptying device shall allow the complete emptying of the residual in the tank when the sprayer is in a horizontal position. It shall be possible to collect the liquid at the outlet without contaminating the operator or equipment parts, e.g. using stays.*
>
> *EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors*

A drain valve has to be present that is capable of completely emptying the tank (Figure 98).

Figure 98: Drain valve positioned at the bottom of the tank.
(an EOS sprayer should allow the safe and complete emptying of the complete sprayer)

6.4.4 Residual volume (drainable) – *PROBLEM*

The drainable residual volume in a sprayer is defined as the amount of liquid that can be collected from the spray tank outlet, typically at the end of the cleaning procedure (diluted spray mixture). In order to minimise the drainable residual volume, several technologies may be adopted.
In EOS tables a 35% environmental weight is given to this problem (Figure 99).

Problem	Technology
Residual Volume drainable Orchard- & Field sprayer 35%	Agitation shut off 30%
	Sump design 20%
	Return valve 30%
	Other connection 15%
	Transfering remaining spray liquid to outside tank 5%

Figure 99: Evaluation structure and environmental weights of technology related to the problem limiting the residual drainable volume

6.4.4.1 Agitation shut-off - *TECHNOLOGY*

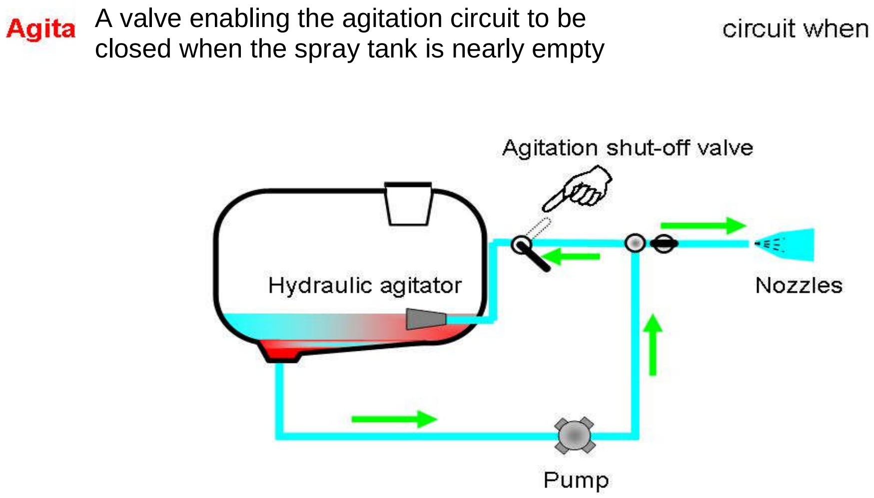


Figure 100: Scheme of an agitation shut-off valve

A dedicated valve to close the agitation system is used to avoid the further circulation of the liquid in the agitation circuit when the tank is nearly empty; a need that enables the main pump to deliver as much spray to the nozzles as technically possible and reduces residual volumes to a minimum. The activation of this agitation valve may be manual, remote or even automatic (for instance when a certain level of liquid is reached in the tank).

6.4.4.2 Sump design – *TECHNOLOGY*

Well designed sumps in the bottom of the tank (Figure 101,102) allow the pump to suck as much liquid as possible into the supply hoses for the solution to be sprayed out. Sump design is, therefore, also an important component that enable the complete emptying of the tank.

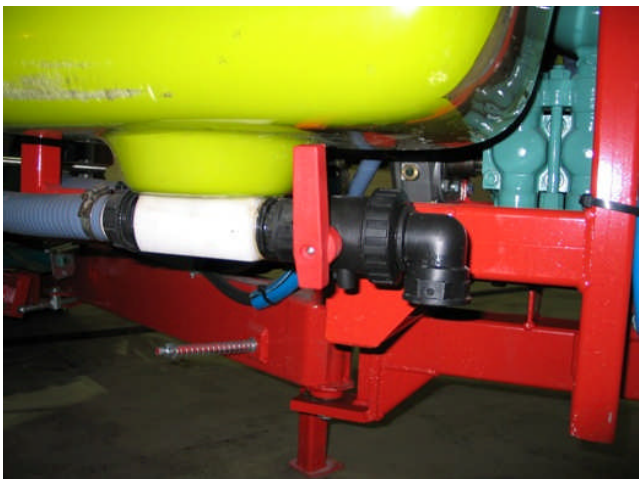


Figure 101: Sump at tank bottom

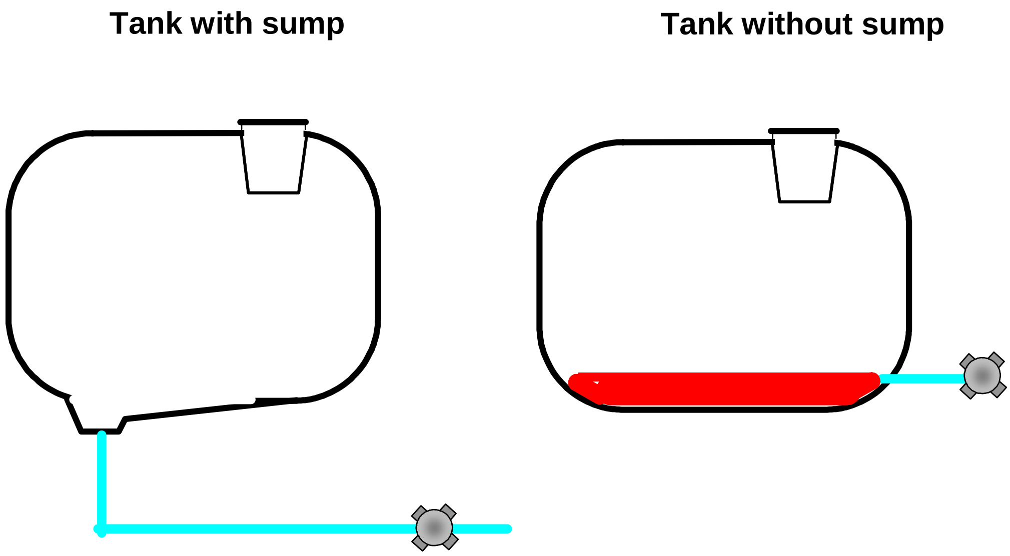


Figure 102: A tank with a sump enables the more complete removal of its content by the pump whilst a tank without a sump may leave a large, consistent residual volume of liquid that the pump cannot extract.

5.6.4.3 Return valve – *TECHNOLOGY*

Three way valves can stop the flow back of liquid from the pressure regulator into the tank and is able to redirect the liquid to the pump suction line (Figure 103,104). This technology significantly reduces the amount of drainable residual volume in the tank and allows the more efficient cleaning of the internal system; rinsing separately the hydraulic circuit and the tank.

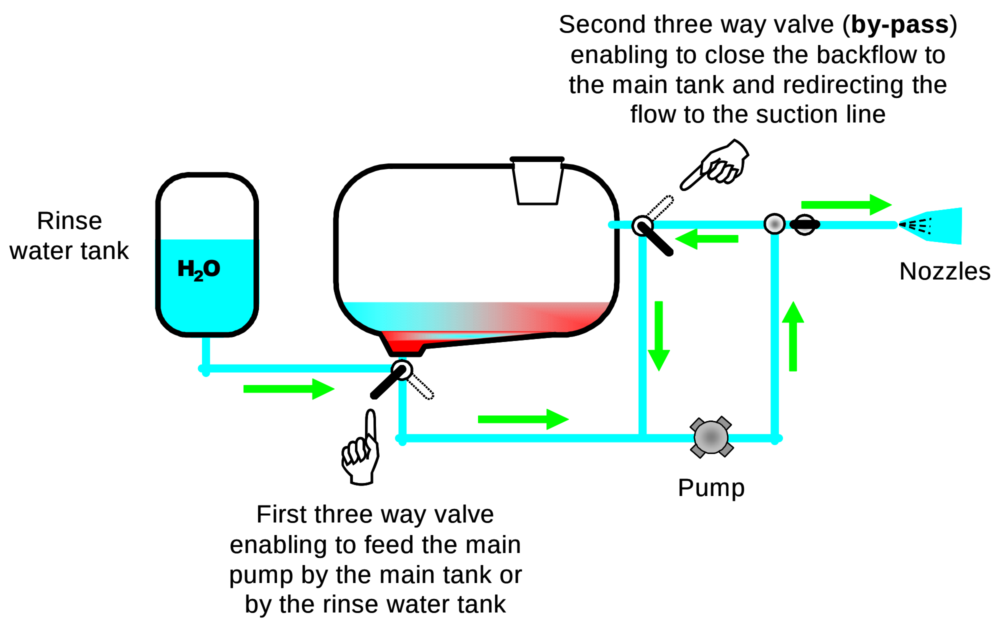


Figure 103: Return valve (by-pass valve) in the hydraulic circuit of a sprayer.

Figure 104: Return valve mounted on an air-assisted sprayer.

6.4.4.4 Other connections – *TECHNOLOGY*

Supplementary drainable valves and connections can be used on sprayers such that localised dead volumes can be drained (Figure 105).

Figure 105: Supplementary drainable connections present on a sprayer.

6.4.4.5 Transfer of any remaining spray liquid to external tank- *TECHNOLOGY*

Quick coupling devices can be provided that enable any remaining liquid in the sprayer tank to be transferred to a collecting/storage tank (Figure 106).

Figure 106: Connection for transferring the liquid to an external tank.

6.4.5 Draining of diluted spray liquid – *PROBLEM*

French and Danish regulations permit the remaining drainable liquid to be left in the field when a certain minimal dilution rate of the drainable residual volume is achieved by the internal cleaning procedure. Where such permits are not granted, any remaining drainable volumes need to be safely collected in an appropriate way. This collection of contaminated liquid from the sump should be capable of being easily and safely done by the operator. In EOS tables a 15% environmental weight is given to this problem.

6.4.5.1 Drain valve – *TECHNOLOGY*

A drain valve (Figure 107) has to be present at the bottom of the tank to enable the tank to be completely emptied. If this drain valve is equipped with a sprinkling system to disperse the residual diluted volume over a wider area then risks of locally exceeding maximum PPP dose rates and point source pollution are further minimised.

Figure 107: Drain valve positioned at the bottom of the tank.

6.5 Spray losses including drift *- RISK AREA*

Risks of environmental contamination during the application of pesticides can be caused by spray losses due to leaks that cause dripping (e.g. from nozzles) or improper choice of spraying parameters. Thus, inappropriate water volume rates, droplet sizes or air settings [such as those used with orchard sprayers to entrain and move spray onto target surfaces] may cause losses. The use of sub-optimised sprayer adjustments may cause severe spray losses, either to the ground, air or non targeted surfaces within or beyond the treatment zone itself.
This risk area has a 10 % weight in the EOS evaluation for field crop sprayers and a 15% weight for orchard sprayers. Orchard sprayer configuration focuses on the distance between nozzles and target, the droplet size and the air settings; factors that very much influence spray losses during the application. In orchard / vineyard applications, the spray projection is vertical and therefore drift risks are much higher to that of field crop sprayers.
Problems relating to EOS risks for spray losses and drift are shown in Figure 108.

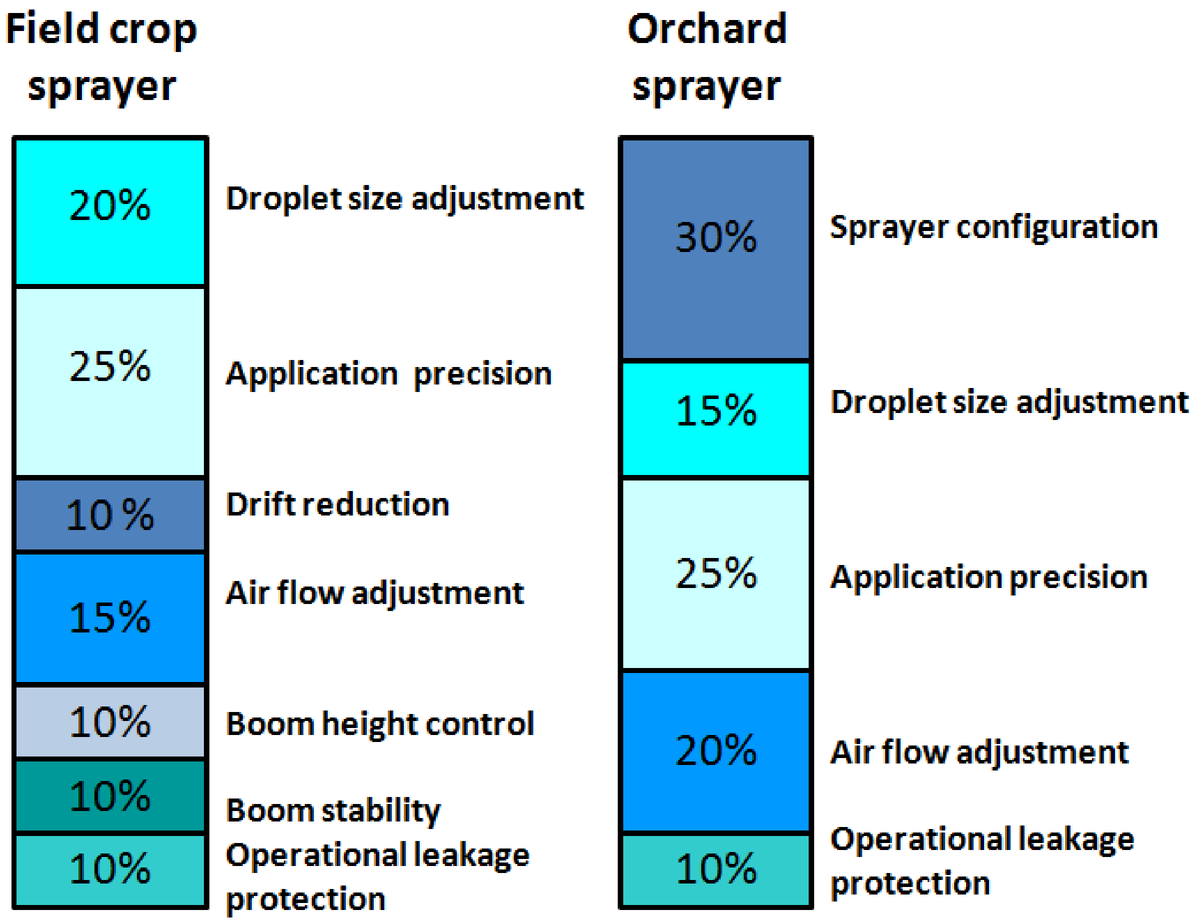


Figure 108: Problems and their weights [%] for the EOPS risk area spray losses and drift.

Problems and relative weights are different between field crop and orchard sprayers because the cropping structures in which they operate are different. Air flow control is very important for orchard sprayers [and some air assisted field crop sprayers] as well as the prevention of leakages during the spray application.

6.5.1 Sprayer configuration (orchard sprayers only) – *PROBLEM*

In orchards and vineyard spraying, the further the sprayed drops have to be projected by the nozzles to contact their intended target surfaces then the greater are the risks of loss. In EOS tables for orchard sprayers a 30% weight is given to this problem.

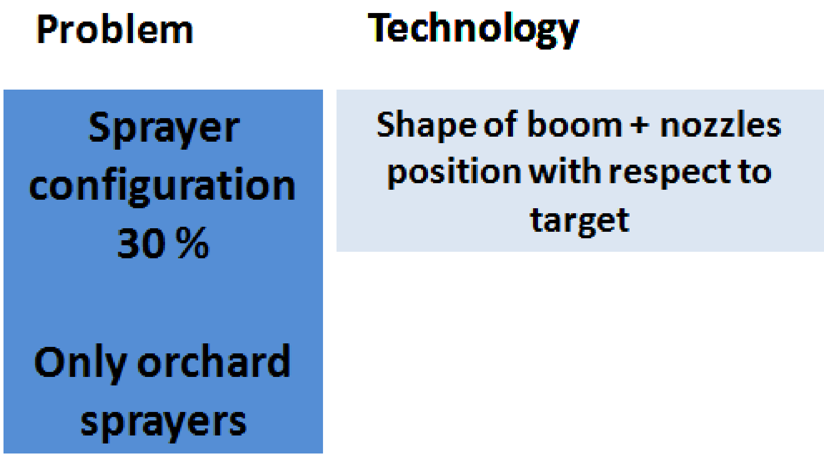


Figure 109: Evaluation structure and weights of technology related to the problem of sprayer configuration for orchard sprayers

6.5.1.1 Shape of the boom and nozzle position with respect to target – *TECHNOLOGY*

Conventional axial fan sprayers (Fig. 110) when operated in orchards need high air volumes to effectively transport droplets to the top of targeted plants. However, air volumes that are excessive – to that specific crop canopy being sprayed - may increase drift risks. Other designs such as cannon sprayers (generally used for high trees, Fig. 111) or multi row sprayers with air spouts and nozzles positioned on the top of the machine to project spray to an adjacent cropping row (Fig. 112) may cause severe risks of spray ground losses and drift. Risks of spray losses can be reduced when the distance between nozzles and target is minimised (for example. using multiple and adjustable air spouts equipped with nozzles, Fig. 113) or collecting/recycling shields are provided (as for tunnel sprayers, Fig. 114).

Figure 110: Conventional axial fan sprayer for vineyards.

Figure 111: – Cannon sprayer creating spray plum at long distance and therefore prone to drift

Figure 112: Pneumatic sprayer equipped with top spouts addressed to the second row

Figure 113: Directed air jet sprayer equipped with multiple and adjustable air spouts, each provided with nozzles.

Figure 114: Tunnel sprayer generating spray plum roughly confined to the target size and collecting part of not deposited spray for recirculation

6.5.2 Droplet size adjustment – *PROBLEM*

Drift risks are closely related to the droplet size of the sprayed liquid: droplets smaller than 100 µm are more prone to drift so this fraction needs to be restricted as much as possible during the application. Essentially, two ways are used to adjust the droplet size: modification of the operating pressure (but this also demands a change in the nozzles flow rate and therefore on the volume rate/PPP dose applied) or a change of nozzle size, design.

Field crop sprayers were given a 20% weight for this problem and orchard sprayers some 15% in EOS tables.

Droplet size adjustment is more important for drift risks with non air assisted field crop sprayers (Figure 115).

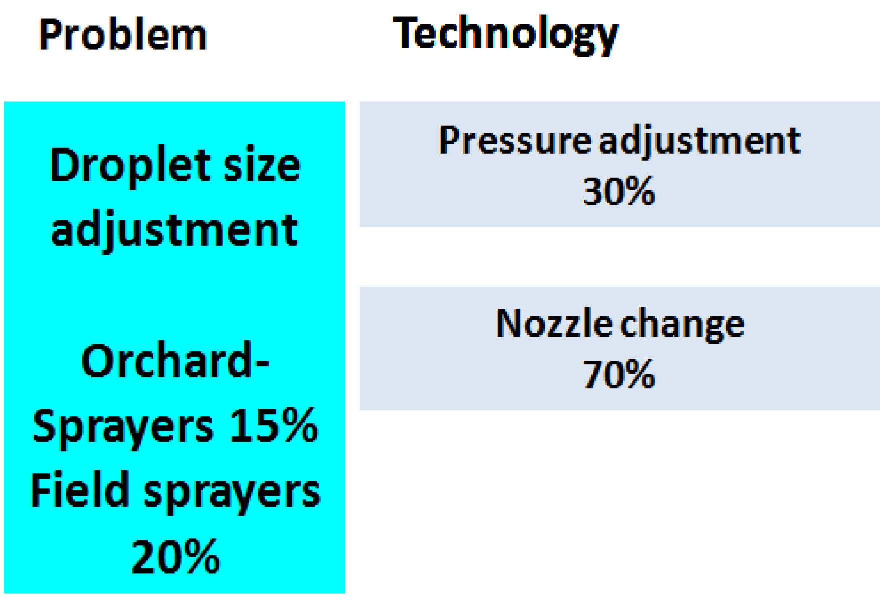


Figure 115: Evaluation structure and weights of technology related to the problem droplet size adjustment

6.5.2.1 Pressure adjustment – *TECHNOLOGY*

Droplet spectra of hydraulic nozzles may be modified with changes to their operating pressure: the higher the operating pressure, the finer are the droplets whilst, conversely, the lower the pressure, the larger are the droplets. However, pressure adjustments to the nozzle, also change the rate of liquid emission; the nozzle flow rate may increase or decrease. To ensure that the correct amount of spray liquid is applied [and, therefore the dose of PPP], requires usually a further compensating change to another calibration related parameter such as spraying speed.

5.5.2.2 Nozzle change - *TECHNOLOGY*

It is recommended to change the nozzles (either in terms of size or of type), to obtain a wider range of control of the droplet spectrum, when making adjustments to achieve the intended level of spray quality and liquid volume rate. Drift mitigation largely depends on the reduction of the fine droplets through this nozzle selection. Changing nozzles may be made manually, removing the whole set of nozzles and replacing them with a new one; a task that takes time and raises risks of drips and subsequent environmental pollution. Multi-holder nozzles are available (Figure 116) which are rotated, to replace one nozzle set with another as, for example, when changing from conventional to air induction nozzles. More sophisticated systems allow the automatic switching from one nozzle set to another (Figure 117).

Figure 116: Multiple nozzle holder.

Figure 117: Electronically managed system for automatic switch from one nozzle set to another.

6.5.2 Application precision – *PROBLEM*

Using only that amount of PPP - that is approved and advised - is a fundamental need of spraying precision. Such accuracy reduces both wastes – such as remnants in the sprayer - and risks, yet ensures optimised biological efficacy with the greatest in-put cost effectiveness. The EOS evaluation rates this need for precision with a 25% weight (Figure 118)

Problem	Technology
Application precision 25%	Target identification 60% / 60% Section control 25 % / 40 % Boom section working width 15% / 0 (first figure field sprayer)

Figure 118: Evaluation structure and weights of technology (%Field crop sprayers/ %Orchard sprayers)

6.5.2.1 Tt identification- *TECHNOLOGY*

Spray [and non spray] targets can be identified using appropriate **sensors** and **interfaces** – within a treatment zone – such that the application process itself can be controlled to selectively spray or not spray those targets only. GPS/GIS equipped systems collate information about the field / crop / weeds to be treated, to generate maps identifying the presence and dispersion of weeds, for example, or the health and vigour of a crop so that only spray solution is emitted if the target is identified by the sensors (Figure 119).

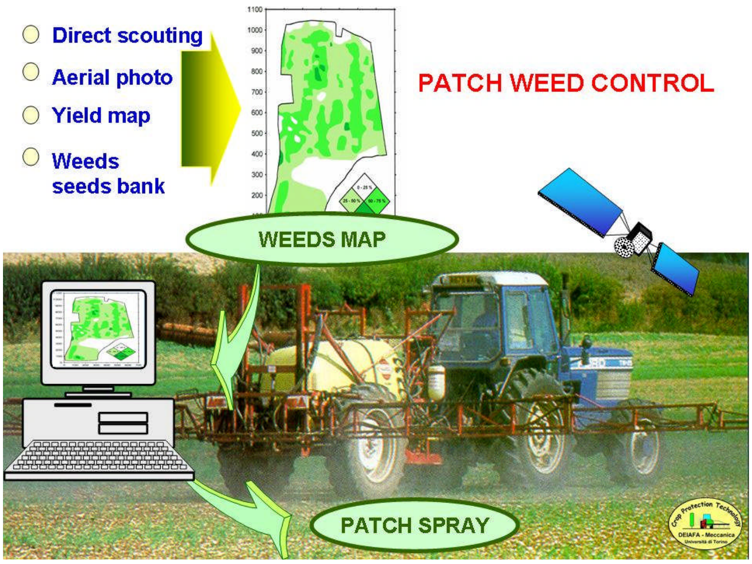


Figure 119: Example of the weed control management for a weed patch.

The presence of weeds in a field may be mapped through scouting by aerial photos or other means with the GPS system used determine the areas that need to be sprayed. Ultrasonic, optical, or infrared sensors may be installed on sprayers to detect, in real time, the presence and the spatial characteristics of the target in order to modulate the spray application accordingly. Interfaces may allow the display of the information received by the sensors or may display the GPS maps of the fields and the spray application can be automatically managed following that information. GPS maps and sensors information can also be displayed in an integrated panel, allowing a further more precise management of the spray applied.

6.5.2.2 Section control- *TECHNOLOGY*

The possibility to switch on and off individual boom sections [rather than always using the full spraying swath] according to the field / crop characteristics are very important to improve the precision of the spray application. The individual boom section control can be operated manually by valves positioned on the sprayer or through electric buttons on a panel in the tractor cab. If combined with GPS and / or sensor systems, the management of individual boom sections can be operated automatically with an electronic system, exploiting the information about the sprayer position and the target presence / characteristics (Figure 120)

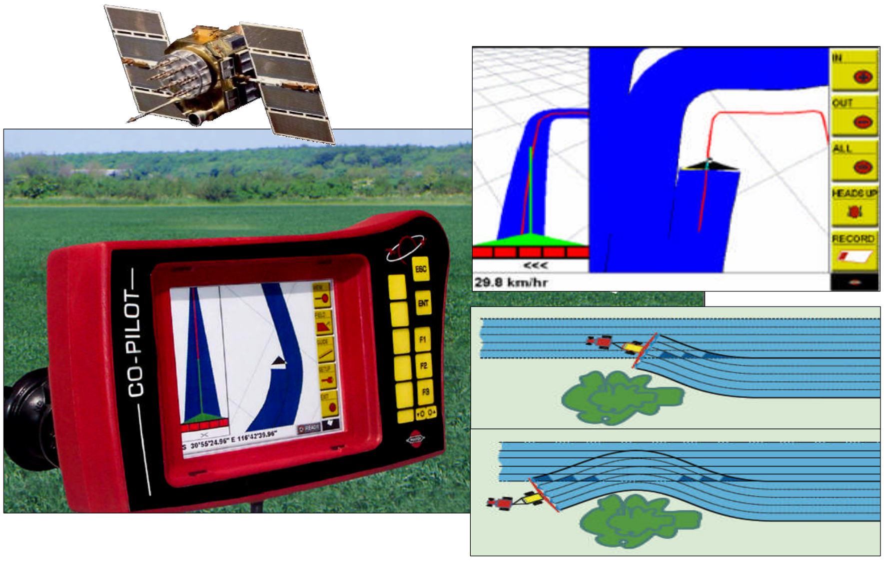


Figure 120: Display panel and functions of automatic swath adjustment based on GPS navigated guiding system and individual section control to avoid spray overlap.

6.5.2.3 Boom section working width (field crop sprayers only) – *TECHNOLOGY*

The shorter the boom sections that can be controlled so will the possibility for more precision, increase. Flexibility in boom spraying widths [within the overall swath width of the sprayer] whilst treating field edges, uneven field shapes and weed patches are some examples where – with less under and over lapping – precision in the uniformity of the PPP dose applied - could increase.

Standard EN 12761-2

The working width shall correspond to the usual widths of seed drills, cultivators, etc. and shall be a whole number multiple of these.
The maximum section widths are:
- 4,5 m for boom width ≤ 24 m;
- 6,0 m for boom width > 24 m.

EN 12761-2:2001 Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

6.5.3 Air flow adjustment – *PROBLEM*

The control of the air flow - generated by the sprayer fan - to ensure an optimal spray distribution and to avoid that air stream carrying the droplets out of the target zone, is critical; both the amount of the air flow and its speed, as well as the direction of the air fluxes, need be adjusted to the target structure itself.
Field crop sprayers are rarely equipped with air assistance and their relative environmental benefits [over conventional field crop sprayers] not obvious; their EOS evaluations are, therefore, considered similar.
EOS orchard evaluation is weighted at 20% whilst field crop sprayers are 15% (Figure 121).

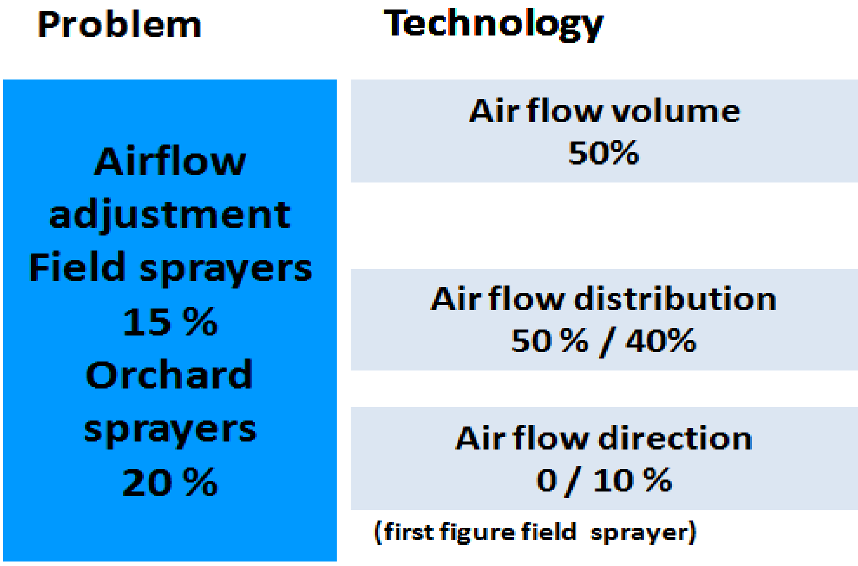


Figure 121: Evaluation structure and weights of technology related to the problem Airflow adjustment (first figure Field crop sprayers , single figure both sprayer types)

6.6.3.1 Air flow volume – *TECHNOLOGY*

Adjusting the characteristics of the applied air flow rate from the sprayer - to the needs for the vegetation to be optimally sprayed - especially in orchard / vine crops (where growth stage, leaf area index, canopy density are some factors to be considered) is essential to improve spray deposition and to minimise drift risks. Air regulation generated by the fan, can usually be made through a gear box offering two rotational speeds; high and low (Figure 122). Further adjustments are possible by changes being made to the ‘pitch’ or angle of the fan blades (Figure 123) or by hydraulic motor regulation; the latter option often used for more fine tuning of the fan rotation speed (Figure 124).

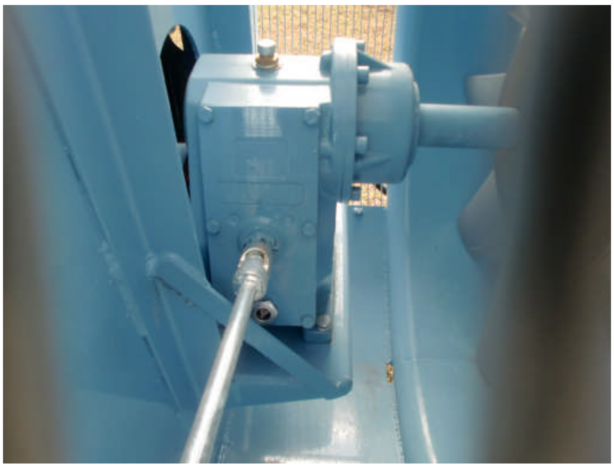


Figure 122: Example of gear box on an orchard sprayer.

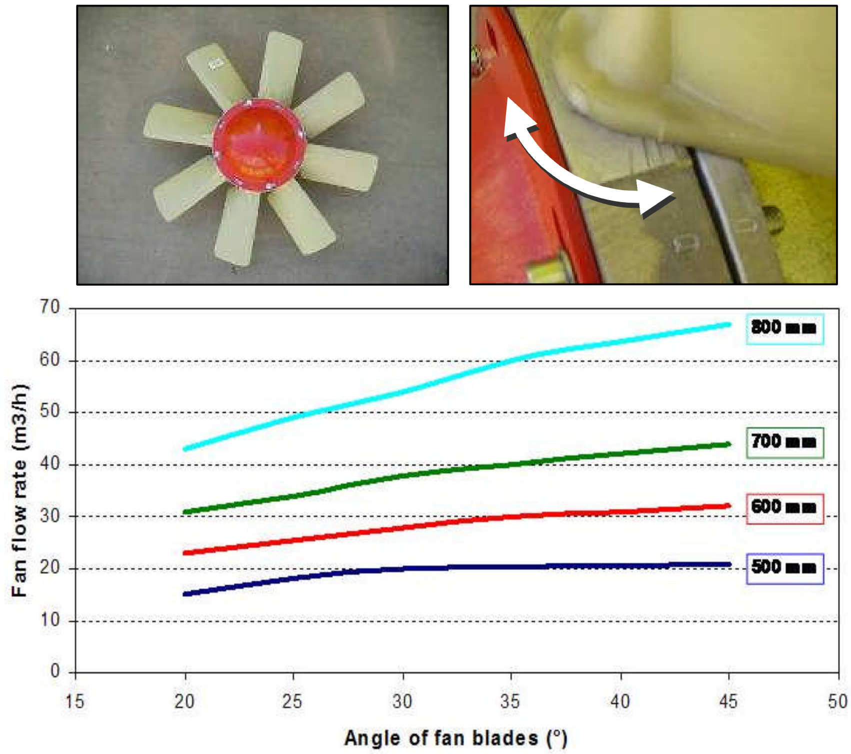


Figure 123: Influence of regulation of angles of fan blades on the airflow rate generated by axial fans of different diameters.

Figure 124: Hydraulically driven fan on a boom sprayer.

Air distribution on orchard sprayers – especially the need to shut off the air stream on one side – is important. This facility for spraying from just one side reduces the unnecessary release of PPP when there are no trees to be sprayed in, for example, the spraying of the outer rows of an orchard. Shields [baffle plates, diversion plates], manually or electrical operated, as well as on/off systems to manage separately the air flow to either side of the sprayer, are suitable technologies used to reduce drift (Figure 125).

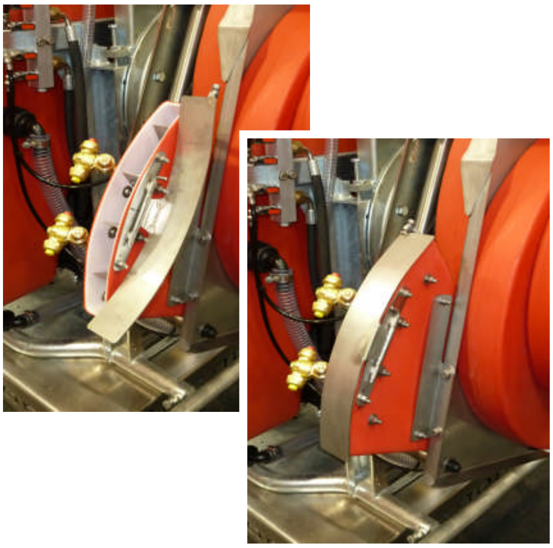


Figure 125: Covering systems on air outlets of orchard sprayers to close the airflow on one side of the sprayer

6.5.3.2 Air flow direction – *TECHNOLOGY*

Air deflectors are devices that enable air fluxes to be directed in the most appropriate way towards the target and to avoid drift. Adjustment the position of these deflectors - to meet these requirements - can be manual (Figure 126), electric (Figure 127) or automatic

Figure 126: Air deflectors to be adjusted manually on a vineyard sprayer

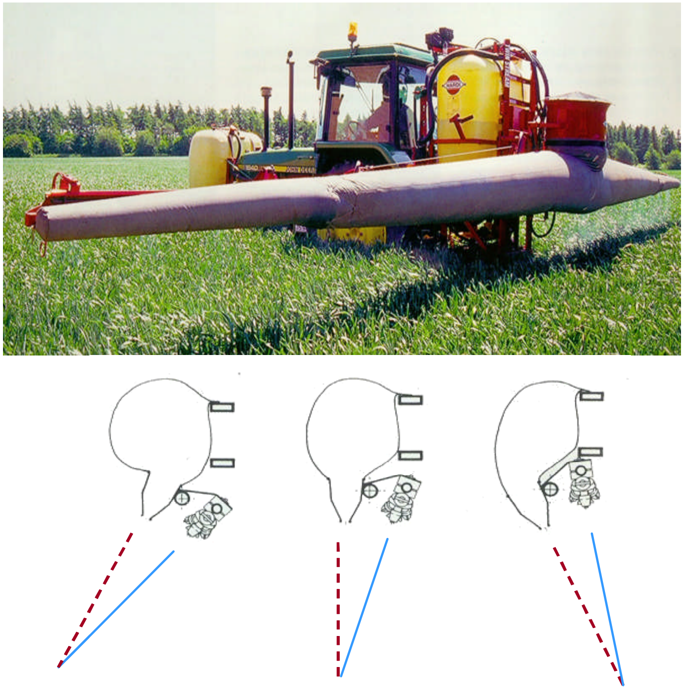


Figure 127: The orientation of the air sleeve output on a boom sprayer can be adjusted according to the purpose of the spray application.

5.5.4 Boom height control (field crop sprayers only) – *PROBLEM*

Drift is very much influenced by boom height when applying PPP to field crops; higher booms generate more drift than lower ones (Figure 128). However, minimal boom heights are advised by manufacturers to ensure uniformity of sprayed deposit and are typically 50 cm above the first foliage or ground contacted by the spray. Some field practices worsen drift risks as, for example, operators with wider booms and / or using faster spraying speeds who tend to raise booms to avoid mechanical damage. Prevention of severe drift risks requires the use of an appropriate boom height with respect to the target structure itself. Adequate systems enabling adjustments of boom height within a convenient range are recommended. A weight of 10% was given to this problem within the risk areas of spray losses and drift reduction.

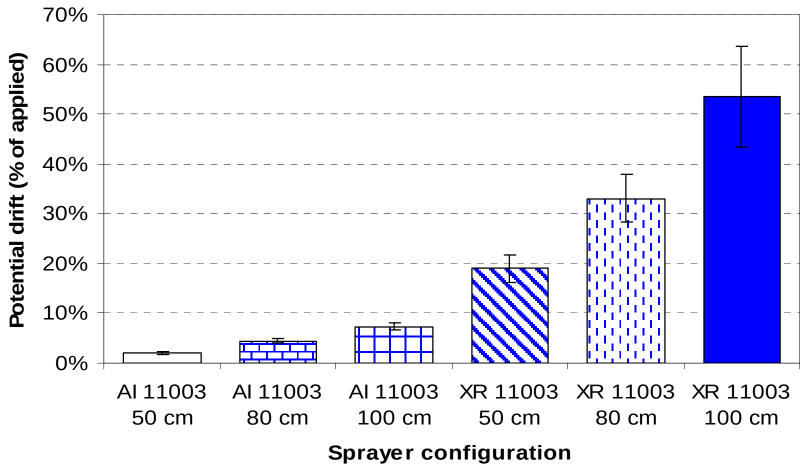


Figure 128: Potential drift assessed on a 10 m boom sprayer with different boom heights and nozzle types (AI = air induction, XR = conventional flat fan nozzles) Balsari et al. 2007

6.5.4.1 Boom height control systems – *TECHNOLOGY*

The height of booms can be controlled manually or by hydraulic systems to pre-determined positions [typically on a vertical support/frame] above the spray target surface. More sophisticated systems operate with sensors to automatically adjust the boom to the correct distance above the target.

6.5.5 Boom stability (field crop sprayers only) – *PROBLEM*

Booms should be kept at a constant height across the whole boom length whilst spraying. It is therefore important that boom stability is ensured by appropriate systems to minimise the excessive boom movements that increase drift risks (Figure 129) and misapplication. EOS field crop sprayer's are 10% weighted for this problem.

Figure 129: Consequences of an not stable boom sprayer.

6.5.5.1 Boom suspension to sprayer frame – *TECHNOLOGY*

Booms, especially wider ones, need a suspension system that reduces boom movements and ensures an even spray application. Short boom lengths (up to 12 m) may be rigid but suspension systems based on pendulum or trapeze devices are largely utilised on booms > 12 m. Combinations of pendulum / trapeze systems - with a damping facility - can further improve the stability of the boom (Figures 130,131).

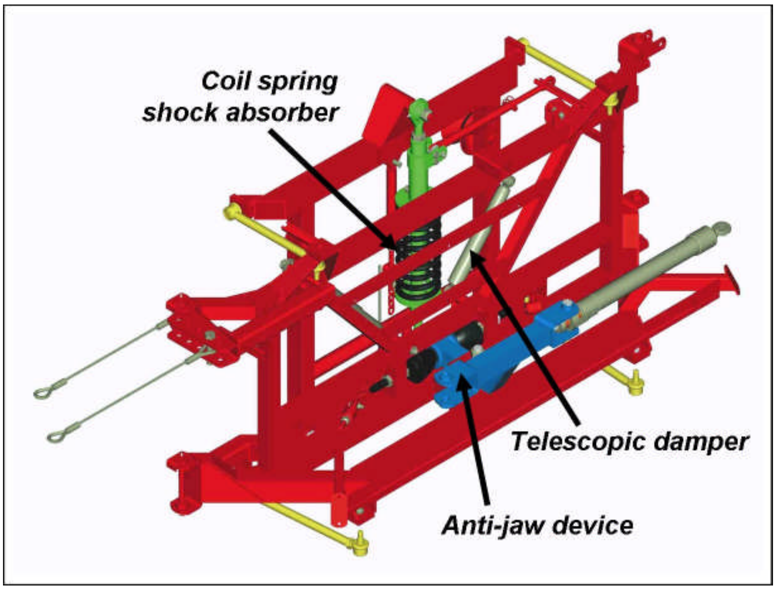


Figure 130: Scheme of shock absorber mounted on the sprayer frame to prevent boom movements during the application.

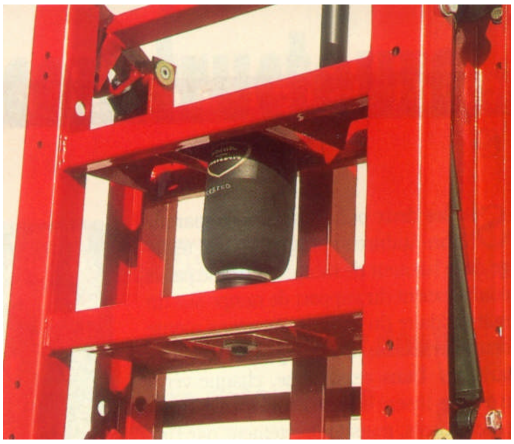


Figure 131: Shock absorber mounted on the frame of a boom sprayer.

6.5.6 Leakage protection whilst operational – *PROBLEM*

Dripping of PPP solution - during transport to the field and the spray application (Figure 132) - may occur especially if the nozzles are not equipped with antidrip devices and if the tank lid is not sufficiently tight. These losses – especially from hard surfaces such as roads or in one place when the sprayer is static in the field - may cause point source pollution and therefore must be prevented. Test protocols for sprayers feature this need to avoid any leaks or drips from nozzles or elsewhere. EOS tables weight this environmental problem at 10% (Figure 133).

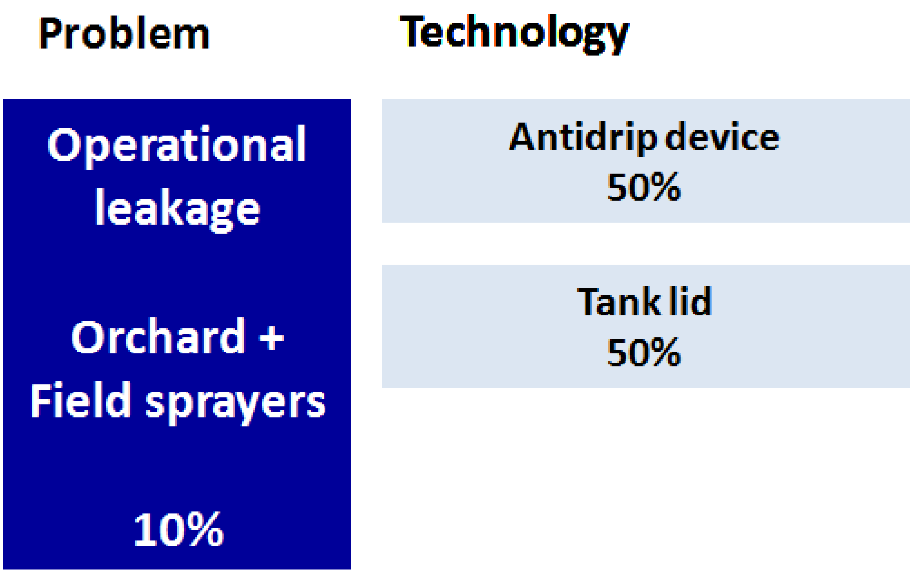


Figure 133: Evaluation structure and weights of technology related to the problem of operational leakage

Figure 132: A leaking / dripping sprayer during its transport from the farm to the field.

6.5.6.1 Antidrip device – *TECHNOLOGY*

Nozzles shall not drip when the spraying is stopped. Indeed, according to EN 13790 (parts 1 and 2), 5 seconds after the spray jet has collapsed no drips shall occur from the nozzles; the quicker that drips stop so the more efficient is the system. Different types of antidrip devices are available (mechanical with diaphragms or spheres; electrical systems or compressed air (Figure 134).

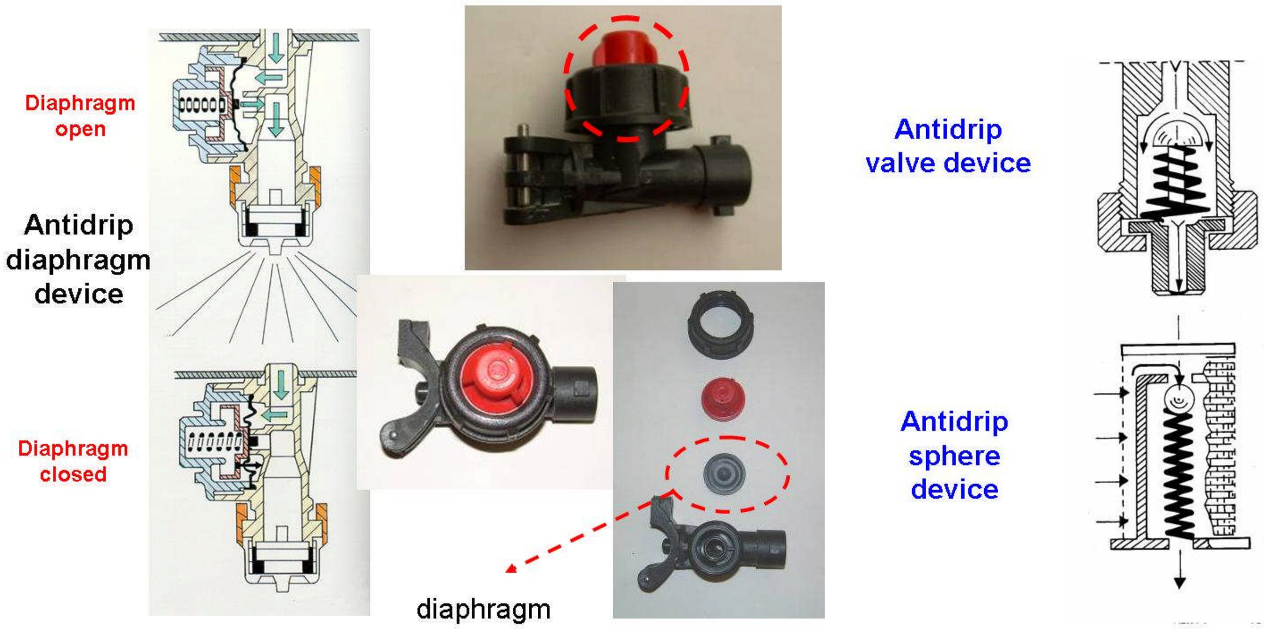


Figure 134: Antidrip diaphragm devices.

6.5.6.2 Tank lid – *TECHNOLOGY*

Standard EN ISO 4254-6

The tank lid shall be:
- attached to the machine, e.g. by means of a chain;
- fitted with a holding device ensuring a closed position either by means of a positive mechanical action or lids fixed by screwing;
- fitted so as to prevent leakage of the spray mixture, e.g. by means of a seal.

EN ISO 4254-6:2009 Agricultural machinery. Safety. Sprayers and liquid fertilizer distributors

Spray solutions during transport to the field - and during the application - shall not leak from its containing tank and due to movements of the sprayer. The tank lid, therefore, has to be capable of sealing the tank against any loss and remain secure in use; a demand that typically requires a threaded [screwed] structure with appropriate seals (Figure 135).

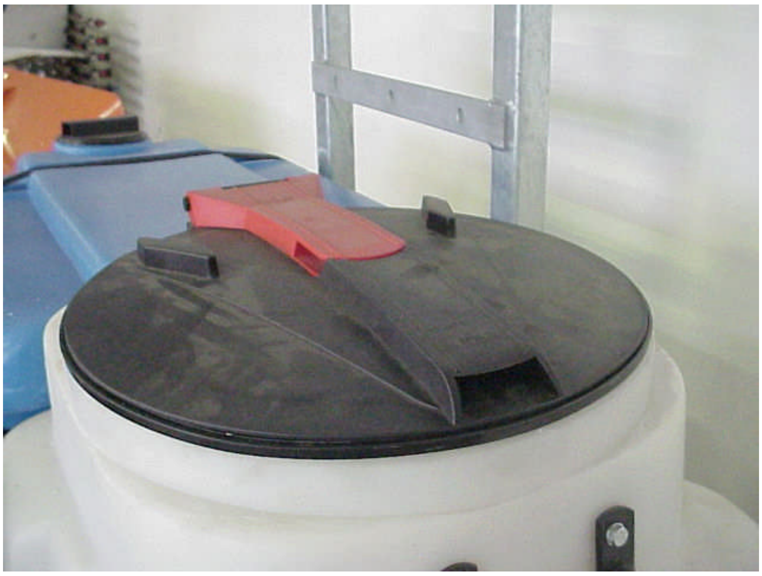


Figure 135: Tight tank cover fixed with a screw

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EN 12761-2 (2001): Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 2: Field crop sprayers

EN 12761-3 (2001): Agricultural and forestry machinery - Sprayers and liquid fertilizer distributors - Environmental protection - Part 3: Air-assisted sprayers for bush and tree crops.

ISO 22368-3 (2004): Crop protection equipment — Test methods for the evaluation of cleaning systems — Part 3: Internal cleaning of tank

EN ISO 4254-6 (2009): Agricultural machinery — Safety — Part 6: Sprayers and liquid fertilizer distributors

ISO 13440 (1996): Equipment for crop protection – Agricultural sprayers – Determination of the volume of total residual.

ISO 4287 (1997): Geometrical Product Specifications (GPS) -- Surface texture: Profile method -- Terms, definitions and surface texture parameters.

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EN 13790-2 (2003): Agricultural machinery - Sprayers - Inspection of sprayers in use - Part 2: Air-assisted sprayers for bush and tree crops.

8. Acknowledgement

The EOS project and its results are a team effort by contributing experts from different areas of competence and expertise.
Experts from science, sprayer manufacturing, public research institutes, crop protection industry and application experts in farmers advisory services.

We would like to acknowledge all the contributions made and also for the sometimes intensive debates in the development and in the evaluation process.
These discussions were always constructive and positive.

Especially the representatives of the technical support group invested a lot of personal engagement and commitment in the development of the EOS tool and the respective documentation and guidance papers.

We would like to acknowledge the English review of the handbook done by Mr. Lawrence King (Bayer CropScience) and Mr. William Taylor.

We would like to thank ECPA for the financial support of the project, which was the base to realize EOS. It also helped to organise EOS in a European context by including project members from 8 European countries, which made EOS a real European project.