Scenarios for exposure of aquatic organisms to plant protection products in the Netherlands

Part 2: Sideways and upward spraying in Dutch fruit crops (final report)

Boesten, J.J.T.I., Adriaanse P.I., Holterman H.J., ter Horst M.M.S., A. Tiktak, van de Zande J.C., Wipfler E.L.

WAGENINGEN UNIVERSITY & RESEARCH

PBL Netherlands Environmental Assessment Agency

Scenarios for exposure of aquatic organisms to plant protection products in the Netherlands

Part 2: Sideways and upward spraying in Dutch fruit crops (final report)

Boesten, J.J.T.I., Adriaanse P.I., Holterman H.J., ter Horst M.M.S., A. Tiktak, van de Zande J.C., Wipfler E.L.

This research was conducted by Wageningen Environmental Research (WEnR), Wageningen Plant Research (WPR) and Netherlands Environmental Assessment Agency (PBL) as part of projects BO-43-102.01-002 and 003 funded by the Dutch Ministry of Agriculture, Nature Management and Food Quality.

Wageningen Environmental Research
Wageningen, July 2021

Reviewed by:
This report is a product of and has been reviewed by all members of the working group on the development of exposure scenarios for aquatic organisms to plant protection products in the Netherlands

Approved for publication:
Bram de Vos, Managing director Environmental Sciences Group of WUR

Report 3100
ISSN 1566-7197

WAGENINGEN
UNIVERSITY & RESEARCH

PBL Netherlands Environmental Assessment Agency

Boesten, J.J.T.I., Adriaanse P.I., Holterman H.J., ter Horst M.M.S., A. Tiktak, van de Zande J.C., Wipfler E.L., 2021. *Scenarios for exposure of aquatic organisms to plant protection products in the Netherlands; Part 2: Sideways and upward spraying in Dutch fruit crops (final report).* Wageningen, Wageningen Environmental Research, Report 3100. 118 pp.; 74 fig.; 12 tab.; 52 ref.

The current Dutch authorisation procedure for calculating the exposure of aquatic organisms to plant protection products needs to be revised. For this reason, Wageningen UR, RIVM and PBL Netherlands Environmental Assessment Agency were asked to develop a new exposure assessment methodology for various crops and application methods. This report describes the methodology for upward and sideways spraying in Dutch fruit crops. In contrast to the current procedure, the new procedure calculates the exposure concentration based on a statistical distribution of the exposure concentration in all relevant Dutch watercourses. The methodology results in a so-called 90th percentile exposure concentration considering all watercourses alongside fields grown with fruit crops. The new methodology takes input of plant protection products by spray drift, drainage and atmospheric deposition into account. Agronomic practices in Dutch apple and pear orchards were considered representative for all (high) pome and stone fruit orchard crops in the Netherlands. An important part of the new methodology is the option to mitigate spray drift deposition by using drift-reducing technologies in a higher spray drift reducing class or by including a wider crop-free buffer zone.

Keywords: pesticides, spray drift, drift reducing techniques, crop-free buffer zone, fruit crops, surface water, aquatic organisms, probabilistic scenario, drainage

The pdf file is free of charge and can be downloaded at https://doi.org/10.18174/549658 or via the website www.wur.nl/environmental-research (scroll down to Publications – Wageningen Environmental Research reports). Wageningen Environmental Research does not deliver printed versions of the Wageningen Environmental Research reports.

Wageningen Environmental Research report 3100 | ISSN 1566-7197

Photo cover: photo by JC van de Zande

Contents

Verification

Report: 3100
Project number: 5200046798

Wageningen Environmental Research (WENR) values the quality of our end products greatly. A review of the reports on scientific quality by a reviewer is a standard part of our quality policy.

Approved reviewer who stated the appraisal,

This report is a product of and has been reviewed by all members of the working group on the development of exposure scenarios for aquatic organisms to plant protection products in the Netherlands.

Approved team leader responsible for the contents,

name: Bram de Vos

date: 3 september 2021

Preface

This report is produced by the working group on the development of exposure scenarios for aquatic organisms to plant protection products in the Netherlands. The report is part of a series of reports produced by the working group on this subject. Part 1 of the series is dedicated to arable crops (Tiktak et al. 2012a). This report (part 2 of the series) focusses specifically on scenario for sideways and upward spraying in Dutch fruit crops. Sideways and upward spraying scenarios for avenue tree nurseries and downwards spraying scenarios for fruit and avenue trees will be reported in a separate report (part 3).

The report is the final report on the exposure assessment methodology for sideways and upward spraying in fruit crops and hence succeeds and replaces the interim-report (Boesten et al. 2018).

We thank Ton van der Linden of the RIVM, who passed away in 2017, for his dedicated contribution to the research presented in this report. We are grateful for all the years of collaboration in the field of plant protection products and the environment.

List of supporting reports

Boesten J.J.T.I., Holterman H.J., Wipfler L., ter Horst M.M.S., van de Zande J.C., Adriaanse P.I., 2018. Scenarios for exposure of aquatic organisms to plant protection products in the Netherlands. Part 2: Sideways and upward spraying in Dutch fruit crops (interim report). Wageningen, Wageningen Environmental Research, Report 2861.

Holterman H.J., van de Zande J.C., Huijsmans J.F.M., Wenneker M., 2017. An empirical model based on phenological growth stage for predicting pesticide spray drift in pome fruit orchards. Biosystems Engineering 154, 46-61, dx.doi.org/10.1016/j.biosystemseng.2016.08.016.

Holterman H.J., van de Zande J.C., Huijsmans J.F.M., Wenneker M., 2018. Development of a spray drift model for spray applications in orchards. Wageningen Research. Report WPR-566, 72 pp. doi: doi.org/10.18174/442091

Holterman H.J., van de Zande J.C., Wipfler E.L., Boesten J.J.T.I., Huijsmans J.F.M., 2021. Development of a probabilistic model for risk assessment of spray drift deposition onto surface waters for fruit orchards in the Netherlands. Wageningen Research. Report WPR-565 (in preparation).

Ter Horst, M.M.S., Wipfler, E.L., Boesten, J.J.T.I., H.Th.L. Massop, D.J.J. Walvoort, 2020. Ditch parameterisation, including the drainage route, for the aquatic exposure assessment of plant protection products in the Netherlands by sideways and upward spraying in fruit orchards. Wageningen, Wageningen Environmental Research, Report 3017.

Van de Zande J.C., Holterman H.J., Huijsmans J.F.M., Wenneker M., 2019. Spray drift for assessment of exposure of aquatic organisms to plant protection products in the Netherlands. Part 2: Sideways and upward sprayed fruit and tree crops. Wageningen Research, Report WPR-564; 86 pp. doi: doi.org/10.18174/448381

Van de Zande, J.C., ter Horst, M.M.S., 2019. Crop related aspects of crop canopy spray interception and spray drift from downward directed spray applications in field crops. Wageningen Research, Report WPR-420, Wageningen. 114 pp. doi: doi.org/10.18174/514310.

Wipfler, E.L., ter Horst, M., Massop, H., Walvoort, D., 2018. Ditch parameterisation for the aquatic exposure assessment of plant protection products in the Netherlands by sideways and upward spraying in fruit orchards. Wageningen Environmental Research rapport; No. 2850.

Summary

The current Dutch authorisation procedure for calculating the exposure of aquatic organisms to plant protection products needs to be revised. For this reason, Wageningen UR, RIVM and PBL Netherlands Environmental Assessment Agency were asked to develop a new methodology for the exposure assessment of aquatic organisms in Dutch surface waters. A general overview of this methodology is given in Tiktak et al. (2012a), while focussing on downward spraying in arable crops. The current report is limited to sideways and upward spraying in Dutch fruit orchards; however, with a few modifications described in this report, it can also be used for sideways and upward spraying in small fruit crops and hops. This report replaces the interim report on upward and sideways spraying (Boesten et al. 2018). The methodology is intended for use in the Dutch authorisation of plant protection products.

A new exposure scenario

The most important part of the new exposure assessment methodology has been the development of a new exposure scenario. This new exposure scenario considers three exposure routes, i.e. spray drift deposition, emission from drainpipes and atmospheric deposition. Hence, as compared to the interim report (Boesten et al., 2018) the exposure routes drainpipe emission and atmospheric deposition were added. The scenario corresponds to the 90th spatio-temporal percentile of the annual maximum concentration in all ditches adjacent to fruit crops in which a plant protection product is applied[1]. In contrast to the current Dutch exposure scenario, the new scenario has been derived systematically using probabilistic and geostatistical modelling. The scenario is intended to be a second-tier approach, to be preceded by a first tier consisting of one FOCUS surface water scenario and succeeded by higher tiers in which parameters can be refined and spray drift mitigated.

The development of the new exposure scenario consisted of two steps: (1) selection of the scenario, and (2) parameterisation of this scenario. For practical reasons, scenario development was done separately for spray drift and drainage entry routes. Hence, for each entry route a space-time combination that corresponds with a 90th percentile concentration has been derived, which are later combined.

In addition to spray drift and drainage, atmospheric deposition has been included to guarantee protectiveness of the exposure scenario. For pragmatic reasons, the simple and conservative approach for arable crops is used, which is in line with current EU practices.

The spray drift scenario

The spray drift scenario has been selected using a spatially distributed probabilistic model consisting of the spray drift model SPEXUS and a metamodel of TOXSWA. SPEXUS considers effects of wind speed, air temperature, crop stage, sprayer fan speed, wind direction, drift reducing technique (DRT class) and width of the crop-free buffer zone. This model was developed based on measurements of 316 deposition-distance curves for apple tree orchards in the Netherlands. The metamodel of TOXSWA is based on the relation between the spray drift deposition and the exposure concentration assuming instantaneous and homogeneous mixing of deposited pesticide in the water of the exposed ditch. The metamodel gives the annual maximum concentration in the adjacent ditch.

The spatially distributed model consisted of 74,000 spatial units. These units are unique combinations of ditch-type, water depth class, geographical orientation of the tree rows and climate series. The simulation period was 100 years. The meteorological time series needed to perform these simulations were derived stochastically from 20 years measured timeseries. Thus, the spatial model generated a frequency distribution of approximately 7,400,000 annual maximum exposure concentrations, from which a 90th-percentile exposure concentration could be derived.

1 In this report the acronym PEC90 will be used for this concentration. PEC is an acronym for Predicted Environmental Concentration.

The shape of the frequency distribution appeared to depend additionally on the number of pesticide applications per year, the season in which the pesticide was applied, the DRT-class of the application technique and the width of the crop-free buffer zone. The consequence was that also the spatial unit corresponding with the 90th-percentile exposure concentration depended on these four factors. The challenge was, however, to generate one single exposure scenario. We therefore ran the spatially distributed model for 350 combinations of DRT-class, width of the crop-free buffer zone and application schemes. This yielded 350 frequency distributions. From these frequency distributions, it was possible to identify one spatial unit that showed a reasonable correspondence with the 90th-percentile exposure concentration. The selected ditch is a watercourse typical of river clay areas. This is also the most important fruit crop type of area in the Netherlands. The water depth in both winter and summer is 30 cm, the width of the water surface is 234 cm, and the width of the bottom of the ditch is 174 cm. The ditch is at the East side of an orchard whose tree rows are in a direction of 340 degrees (i.e. a bearing of 20 degrees West of the map North).

As mentioned above, the spatially distributed model generated 7,400,000 maximum annual concentrations from which the 90th-percentile exposure concentration was derived. The selected scenario (i.e. spatial unit) is based on only one of these 74,000 units. So a link had to be made between the calculation results for the selected spatial unit and the calculation results from the spatially distributed model. This was done by calculating the temporal frequency distribution for the selected spatial unit and to assess which temporal percentile of the selected unit corresponded to the 90th-percentile exposure concentration from the spatially-distributed model. This percentile was further used to derive the PEC90 from a calculation with the parameterised scenario. Thus, for each of the 350 calculations with the spatially distributed model the corresponding temporal percentile was derived; most temporal percentiles were between 40 and 60 percentile.

The drainpipe scenario

An orchard field experiment where drainage was measured was not available, so we based the drainpipe scenario on a field experiment in an arable cracking clay soil. This field experiment dataset – also called the Andelst dataset – has previously been used to derive the drainpipe scenario for arable soils; however, crop specific properties including irrigation and interception were changed to reflect fruit orchards instead of arable crops. Moreover, the grass strip and the fruit strip were parameterised separately to reflect heterogeneity of management practices in fruit orchards. The drainpipe scenario was run using the PEARL model for a 15-years period, so the result is a temporal frequency distribution consisting of 15 annual maximum concentrations. From this frequency distribution, one annual maximum concentration was selected to be the endpoint of the drainage exposure assessment. This endpoint is the 90th overall concentration simulated with a macropore version of the spatially distributed model GeoPEARL. It turned out the 63rd percentile of the temporal frequency distribution corresponded well with the overall 90th spatio-temporal percentile from GeoPEARL simulations.

Ditch parameterisation

The scenario ditch has been selected using the spatially distributed spray drift deposition model described above. As a final step, the TOXSWA model has been parameterised for the scenario ditch. The parameterisation reflects typical characteristics of Dutch flow situations where water can flow in two directions: in winter excess water is discharged, and in summer there is inflow of water to allow for irrigation. So the model includes both an upstream/downstream area at both sides of the 100 m evaluation ditch. Water flow velocities and residence times were derived from simulations with a regional hydraulic model typical of the area in which the scenario ditch is situated. The simulations show a median residence time in the 100 m evaluation ditch of approximately one day. Sediment properties were derived from one of the field measurements at four locations in the Netherlands.

The TOXSWA model calculates the exposure concentration in water. Various fate processes are considered including convection, diffusion, degradation, and adsorption to organic matter. The simulation length is 20 years, from which the first five years are used as a 'warming-up' period. TOXSWA receives input from spray drift, drainage, and atmospheric deposition. The model also calculates the concentration is sediment. The calculated sediment concentration that corresponds to the PEC90 in surface water is a reasonable estimate for the 90th percentile sediment concentration.

Combining spray drift and drainage as entry routes in one scenario
The spray drift scenario and the drainage scenario were derived separately, each with its own temporal percentile. A robust protocol had to be developed to determine a temporal percentile that is appropriate for both drainage emission and spray drift deposition. The protocol worked out in this study is as follows. The simulation is run for the required number of years. For each year, the annual maximum of PEC is recorded and for each of these it is determined whether spray drift or drainage was the more important factor. If in more than 2/3 of the years the annual maximum PEC value is due to spray drift, then this route is considered dominant and the temporal percentile for spray drift is used. On the other hand, if in more than 2/3 of the years the annual maximum PEC value is due to drainage, then that route is considered dominant and the temporal percentile for drainage is used (which is 63%). In other cases both entry routes appear to be significant. Then the higher temporal percentile of the two entry routes is used, conservatively.

Example simulations
Example calculations carried out for three example substances in apple tree orchards showed that in most case spray drift was the dominant exposure route. However, when a sprayer was used in the spray drift reduction class of 99%, drainage became the dominant exposure route (with the exception of strongly adsorbing substances). This does not mean, however, that drainage and atmospheric deposition can be completely neglected in other cases. The example simulations confirmed that accumulation of substances did not occur over the years, which results from the short residence time of substances in the water layer. The example calculations further showed that even for strongly adsorbing substances, the length of the warming-up period was sufficiently long to establish a stable substance mass in the sediment. The example calculations also showed that in cases where drainage is the dominant exposure pathway, the exposure concentration is found to be sensitive to the application date. This is undesirable as the outcome of the assessment in such cases is not robust and may lead to ambiguity in the calculation of the PEC90. In dialogue with the risk managers, it was decided to define application schemes in the software (i.e. DRAINBOW) using BBCH crop stages rather than application dates. This approach is in line with the approach developed by EFSA within the framework of the so-called FOCUS-repair action.

Samenvatting

De Nederlandse toelating methodiek voor het bepalen van de blootstelling van waterorganismen van gewasbeschermingsmiddelen moet worden geactualiseerd. Daarom is er een nieuwe methodiek ontwikkeld door Wageningen UR, RIVM en PBL. Dit rapport beperkt zich tot de blootstellingsmethodiek voor toepassingen via zijwaartse en opwaartse bespuitingen in de Nederlandse fruitteelt. Met enkele aanpassingen kan de methodiek ook worden gebruikt voor (houtig) klein fruit en hop. Het rapport vervangt het interim rapport voor zijwaartse en opwaartse bespuitingen (Boesten et al. 2018) en bouwt tevens voort op Tiktak et al. (2012a) dat een vergelijkbare methodiek beschrijft voor akkerbouwgewassen.

Een nieuw blootstelling scenario
Het belangrijkste onderdeel van de nieuwe beoordelingsmethodiek is het nieuwe blootstellingscenario. Dit scenario houdt rekening met drie blootstellingsroutes richting oppervlaktewater, namelijk drift depositie, emissie via drainpijpen en atmosferische depositie. In het interim rapport uit 2018 werd alleen rekening gehouden met drift repositie. Omdat bij sterk drift reducerende maatregelen de bijdrage van de andere twee routes aanzienlijk kan zijn, zijn deze routes ook meegenomen in het nieuwe scenario.

Het scenario geeft het 90ste ruimtelijk-temporeel percentiel van de jaarlijkse maximum concentraties in sloten naast fruitboomgaarden waarin een gewasbeschermingsmiddel wordt toegepast[2]. Het scenario is systematisch afgeleid waarbij gebruik wordt gemaakt van probablische en geo-statistische modellen. Het vormt de tweede trap in de getrapte blootstellingsmethodiek, waarbij de eerste trap wordt gevormd door een van de (EU) FOCUS oppervlakte scenario's en waarbij de derde en hogere trappen mogelijke parameterverfijningen in het scenario bevatten.

Het nieuwe scenario is ontwikkeld in twee stappen waarbij eerst het scenario is geselecteerd en vervolgens het geselecteerde scenario is geparameteriseerd. Uit praktische overwegingen zijn de scenario's voor de drift depositie en drainpijp emissie los van elkaar ontwikkeld (voor elke route is een 90ste percentiel blootstellingscenario ontwikkeld) en zijn deze daarna gecombineerd. De bijdrage van atmosferische depositie is daarna toegevoegd aan het gecombineerde scenario. Uit pragmatische overwegingen is een eenvoudige en conservatieve benadering gekozen voor het bepalen van de bijdrage van atmosferische depositie. Deze benadering komt overigens overeen met die van de EU.

Het drift depositie scenario
De selectie van het drift depositie scenario was gedaan met behulp van een ruimtelijk verdeelde probablistisch model dat gebruik maakt van het drift model SPEXUS en een meta-model van het oppervlaktewatermodel TOXSWA.

SPEXUS berekent drift depositie op basis van windsnelheid, luchttemperatuur, gewasstadium (BBCH), instelling van de spuitapparatuur, windrichting, drift reducerende techniek (DRT klasse) en breedte van de gewasvrije bufferzone. Dit model is gebaseerd op 316 drift-depositie metingen in Nederlandse appelboomgaarden.

Het metamodel van TOXSWA bevat een eenvoudige relatie tussen de spuitdrift depositie en blootstellingsconcentratie waarbij uitgegaan wordt van instantane en gelijkmatige menging in de sloot. Het model berekent voor elke combinatie van toepassingen de maximale concentratie in de sloot in een kalenderjaar.

Het ruimtelijk verdeelde model bevat ca 74 000 ruimtelijke eenheden. Deze eenheden zijn unieke combinaties van slootypen, waterdiepteklassen, de oriëntatie van de bomenrijen en meteorologische

[2] In dit report wordt het acroniem PEC90 gebruikt voor de concentratie. PEC staat voor 'Predicted Environmental Concentration'.

omstandigheden. Elke berekening met het ruimtelijk verdeelde model is gedaan voor 100 simulatiejaren. De 100 jaar-tijdreeks met weergegevens was daarbij stochastisch afgeleid van een beschikbare tijdreeks van 20 jaar. Elke berekening met dit model leverde dus ca 7 400 000 blootstellingsconcentraties op (jaarlijkse maxima); deze werden samengevat in de vorm van een cumulatieve frequentieverdeling waarvan de PEC90 werd afgeleid.

Er zijn een viertal factoren die invloed hebben op de frequentieverdeling van de concentraties en daarmee de PEC90. Dit zijn het aantal toepassingen in het jaar, het seizoen waarin wordt toegepast, de DRT-klasse van de toedieningstechniek en de breedte van de gewasvrije zone. Van de verschillende combinaties van toepassingen en mitigerende maatregelen moest één ruimtelijke eenheid worden geselecteerd die voor al deze combinaties de PEC90 geeft. Daartoe is het ruimtelijke model 350 keer gerund resulterend in 350 frequentieverdelingen en 350 PEC90s. Voor al deze verdelingen is een ruimtelijke eenheid geselecteerd waarmee deze 350 PEC90s kunnen worden berekend. Deze geselecteerde eenheid bestaat uit een sloot dat typisch voorkomt in het rivierengebied. In deze regio komt veel fruitteelt voor. De waterdiepte van de sloot is 30 cm in de zomer en in de winter. De sloot is gesitueerd aan de oostzijde van de behandelde boomgaard met een richting van de bomenrij die 20^{o} ten westen van het noorden ligt (uitgaande van 360^{o} voor de volledige noord-oost-zuid-west cirkel) en is gelegen in het meteodistrict Herwijnen.

Het ruimtelijke model genereert dus 7.400.000 jaarlijkse maxima. De ruimtelijke eenheid die is geselecteerd is één van deze 74.000 ruimtelijke eenheden. Voor de 350 mogelijke combinaties moest er een link worden gemaakt tussen de resultaten van de selecteerde ruimtelijke eenheid en de resultaten van het ruimtelijke model. Dit is gedaan door voor elk van de 350 combinaties een temporeel percentiel te kiezen dat overeenkomt met de PEC90 van de uitkomsten van het ruimtelijke model. Elk van de 350 berekeningen met het ruimtelijke model leverde zo een temporeel percentiel op Dit ruimtelijk percentiel ligt voornamelijk tussen de 40-60 percentiel.

Het drainage emissie scenario
De uitwerking van het scenario voor emissie vanuit drainpijpen is gebaseerd op beschikbare experimentele gegevens van een akkerbouwveld met scheurende kleigrond (de 'Andelst dataset'). Van dezelfde dataset is gebruik gemaakt voor de het drain-emissie-scenario voor akkerbouwgewassen. Experimentele gegevens van fruitboomgaarden waren niet beschikbaar.

Ten opzichte van de aanpak van de akkerbouwmethodiek zijn teelt-specifieke eigenschappen aangepast zoals bijv. de irrigatie en de interceptie door het gewas. Daarnaast is er rekening gehouden met de bomenrijen en de zwartstrook eronder en de aanwezigheid van grasstroken tussen de boomrijen. Deze twee strooktypen hebben afzonderlijke model-geparameterisaties voor de simulatie van het effect op de uitspoeling naar het oppervlaktewater, die vervolgens samenkomt in één geparameteriseerd scenario. De simulatieperiode van dit scenario beslaat 15 jaar en resulteert in 15-jaarlijkse maximum concentraties in het oppervlaktewater.

Tegelijkertijd is er met ruimtelijk verdeelde model GeoPEARL (in de versie waarbij ook het effect van macroporien wordt gesimuleerd) een berekening uitgevoerd met verschillende modelstoffen. De PEC90 berekend met GeoPEARL en het geparameteriseerde scenario is vergeleken. Het 63ste temporeel percentiel van het scenario is daarbij gekozen zijnde het percentiel dat voor alle modelstoffen een concentratie geeft dat gelijk is of hoger dan de (overall) PEC90.

Sloot parameterisatie
De geselecteerde ruimtelijke eenheid heeft een sloottype dat typisch voorkomt in het rivierenlandgebied, met een mediane waterdiepte van 30 cm. Het TOXSWA model is geparameteriseerd voor dit type sloot waarbij rekening is gehouden met Nederlandse hydrologische omstandigheden. Stroomsnelheden en verblijftijden zijn afgeleid van een gekalibreerd regionaal hydrologisch model. In Nederlandse polders kan het water in een sloot beide kanten opstromen. In overeenstemming met de praktijk simuleert het TOXSWA model waterafvoer in de winter en watertoevoer in de zomer (voor de irrigatiebehoefte van de fruitbomen). De evaluatie sloot is 100 m lang. De simulaties laten een mediane verblijftijd in de 100 m sloot zijn van één dag. De sediment

eigenschappen in de sloot zijn afgeleid van metingen in het veld, waarbij één van de vier gemeten locaties is geselecteerd.

Het TOXSWA model berekent de stofconcentratie in water. Chemische processen die worden gesimuleerd door het model zijn onder andere convectie, diffusie, dispersie, afbraak, en adsorptie aan organische stof. De simulatieperiode beslaat 20 jaren waarvan de eerste vijf jaren zogenaamde opwarmjaren zijn. TOXSWA ontvangt invoer van gewasbeschermingsmiddel via drift, drainage en atmosferische depositie. De concentratie in sediment wordt ook door het model berekend. Naar verwachting is de sediment concentratie die hoort bij de PEC90 van het oppervlaktewater scenario redelijke in overeenstemming met het 90 percentiel voor de concentratie in het sediment.

De combinatie van drift en drainage

De scenario's voor drift depositie en voor de drainage zijn apart afgeleid, met elk een eigen temporeel percentiel. Voor de combinatie van beide scenario's is een protocol worden ontwikkeld dat een van de temporeel percentielen kiest. Dit protocol moet beschermend zijn, maar niet te streng. Het uitgewerkte protocol is als volgt: de simulatie wordt uitgevoerd voor het aantal jaren dat is ingesteld (15 jaar). Van elk van de jaarlijkse maximum concentraties wordt vastgesteld of deze is veroorzaakt door drainage, drift of beiden. Als meer dan 2/3 van de jaren wordt veroorzaakt door drift dan wordt het temporeel percentiel gekozen van de drift. Als meer dan 2/3 van de jaren wordt veroorzaakt door drainage, dan wordt het temporeel percentiel van drainage gekozen (dit is het 63%). In de andere gevallen wordt de hoogste van de twee temporeel percentielen gekozen.

Voorbeeldberekeningen

De voorbeeldberekeningen die zijn uitgevoerd en beschreven in dit rapport zijn geïnspireerd op drie stoffen die regelmatig worden en werden gebruikt in de appelteelt. Over het algemeen is bij toepassingen in fruitbomen drift depositie de dominante blootstellingsroute. Wanneer een 99% reducerende spuit wordt gebruikt wordt emissie uit drainage de dominante route (dit geldt niet voor sterk adsorberende stoffen). De bijdrage vanuit drainage of atmosferische depositie zeker niet verwaarloosbaar voor alle andere gevallen.

De voorbeeldberekeningen laten verder zien dat door de korte verblijftijden in de sloot accumulatie in de sloot niet optreedt.

De opwarmperiode van vijf jaar blijkt verder voldoende om een stabiele concentratie in het sediment op te bouwen. Dit geldt ook voor sterk adsorberende stoffen.

De berekende PEC90 wordt gevoelig voor de toedieningsdatum wanneer drainage de dominante route is. Dit is een onwenselijke situatie omdat de uitkomsten van een assessment in dat geval niet robuust zijn. In overleg met de risico managers worden de toedieningsmomenten gekoppeld aan het ontwikkelstadium van het gewas (BBHC stadium). De gebruiker kan een ontwikkelstadium opgeven en het software instrument (DRAINBOW) berekent de bijbehorende datum. Deze aanpak komt overeen met de aanpak die wordt voorgesteld door EFSA (FOCUS repair).

1 Introduction

1.1 Background

Around 2007 the Dutch government initiated a considerable amount of activities to improve the Dutch pesticide risk assessment for aquatic organisms. A series of workgroups were started dealing with the effect assessment, the handling of multi-stress, emissions from soilless and soil bound covered crops and interpretation of monitoring results for regulatory use.

Then also a workgroup was started to revise the Dutch exposure assessment of aquatic organisms. The current Dutch exposure assessment is based on pesticide entries via spray drift only and this was considered inappropriate after the development of the FOCUS surface water scenarios which clearly indicated the importance of the input from drainpipes, considering also that 40% of the Dutch arable fields have drainpipes (Tiktak et al., 2012a). So, the focus was on including emission from drainpipes. Between 2007 and 2012 an exposure assessment procedure for downward spraying in field crops was developed which resulted in a series of reports (Tiktak et al., 2012a, 2012b; Van de Zande et al., 2012) and a β-version of the corresponding DRAINBOW software package. Between 2013 and now, an exposure assessment procedure for sideways and upward spraying in fruit crops and lane trees was developed.

After the finalisation of the procedure for downward spraying in field crops, two weaknesses in the approach were discovered: (i) ditches that fall temporarily dry were included in the spatial population of water bodies and this is considered inappropriate now because EFSA (2013) indicated that the current effect assessment is valid for permanent water bodies only; (ii) the spatial population of water bodies was limited to ditches that receive both input from spray drift and drainpipes based on the assumption that these ditches would have higher exposure concentrations than ditches that receive input from either spray drift or drainpipes whereas Van de Zande et al. (2012) have shown that this assumption may be incorrect.

As follows from the above, the aim of the work was to develop an exposure assessment for sideways and upward spraying in fruit crops, taking into consideration the lessons learned from the work on downward spraying in field crops. The developed exposure assessment methodology is summarized in this document. Dutch apple and pear orchards were used as example orchards when information was needed on agronomical management practices such as orchard configuration and irrigation. The derived scenario is however considered representative for all pome and stone fruit orchard crops. Details on different aspects of the methodology can be found in Holterman et al. (2017, 2018, 2021), Wipfler et al. (2018), Ter Horst et al. (2020), Van de Zande and Ter Horst (2019), and Van de Zande et al. (2019). Furthermore, this report contains results of a number of example simulations.

This report is the final report on the exposure assessment methodology for sideways and upward spraying in fruit crops and hence succeeds the interim-report (Boesten et al., 2018). In Boesten et al. (2018) the scenario for the emission route via drift deposition is described. This final report includes all relevant emission routes to surface water, i.e. spray drift deposition, emission via drainpipes as well as atmospheric deposition.

1.2 The exposure assessment goal

As described by EFSA (2010), regulatory exposure assessments for plant protection products have to be based on well-defined exposure assessment goals. Definition of such goals includes the following elements (Boesten, 2017): (i) the Ecotoxicologically Relevant type of Concentration (ERC), (ii) the temporal dimension of this type of concentration, (iii) the type of spatial unit (acronym SU), (iv) the spatial dimension of this type of spatial unit, (v) the spatial population of spatial units (acronym SPSU[3]), (vi) the multi-year temporal population of concentrations (acronym TPC; this is only relevant for alternating cropping systems), (vii) the percentile to be taken from the spatio-temporal population of concentrations (acronym STPC; this relates to the level of protection). The ERC was defined as concentration of freely dissolved chemical in the water phase. Its temporal dimension includes different options, such as the annual maximum concentration and the annual maximum of a time-weighted average concentration (see EFSA, 2013, p. 109-120 for more details). The type of SU was defined as a ditch. Its spatial dimension was defined by specifying that (i) it carries permanently water and has a maximum width of the water surface of 6 m, (ii) the effect assessment applies to a ditch of a length of 100 m, and (iii) the average concentration over this 100 m is used for the effect assessment. The SPSU was defined as all units adjacent to Dutch orchards sprayed with this pesticide (which has the consequence that also units receiving no pesticide input are included in the SPSU). This includes orchards with and without drainpipes. The TPC was defined as the ERC values of all years of a certain spatial unit (non-controversial because fruit crops are permanent crops). The STPC is the weighted combination of TPCs of all SUs countrywide. The percentile to be taken from the STPC was an overall 90th percentile, without further restrictions in the space-time domain (as recommended by EFSA, 2013). See Figure 1 for a schematic overview of these seven elements of the exposure assessment goal together with the selected descriptions of these elements.

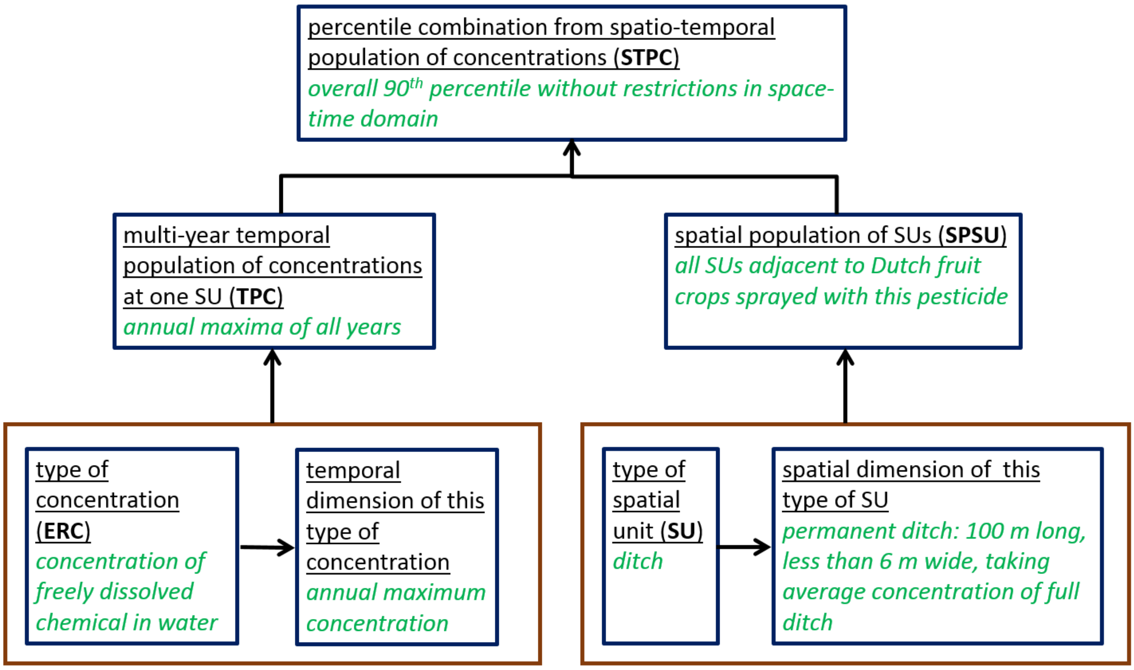

Figure 1 *Schematic overview of the dependencies between the seven elements of the definition of the exposure assessment goal, including the description of these elements. The seven elements are underlined and their descriptions are in italic.*

Although the temporal dimension includes different options, the scenario selection procedure as presented in this work was based only on the annual maximum concentration, i.e. the same approach as followed for the scenario for downward spraying in field crops; see Tiktak et al. (2012a, p. 17) for detailed considerations on this aspect. We refer to the annual maximum concentration as the Maximum Predicted Environmental Concentration, PEC_{max}.

[3] See Section 0 for a list of the abbreviations.

1.3 Exposure routes

Pesticide can enter a nearby water course via different entry routes (Figure 2). The main routes considered for fruit orchards are spray drift deposition and emission from drainpipes.

The scenario for downward spraying in field crops (further abbreviated to '*d-fi* scenario') included emission from drainpipes using an approach based on (i) simulations with GeoPEARL for a range of substances considering all ditches adjacent to field crops (including the temporarily dry ditches) and on (ii) a scenario parameterised for the 'Andelst' location. These simulations showed that about the 60^{th} percentile in time at the 'Andelst' location corresponded well with the desired overall 90^{th} percentile (Tiktak et al., 2012b). The parameterisation of the emission from drainpipes at this 'Andelst' location was based on an extensive field experiment (Scorza et al., 2004). The drainpipes appeared to contribute significantly to the exposure concentrations in the *d-fi* scenario (Tiktak et al, 2012a).

The workgroup proposed in 2013 to the responsible ministries to use also this Andelst drainpipe scenario as part of the scenario for sideways and upward spraying in fruit crops (called '*su-fr* scenario') as a quick solution based on the assumptions (i) that the contribution from spray drift would be much larger for *su-fr* than for *d-fi* and (ii) that the Andelst scenario would be conservative for *su-fr* because fruit crops would be predominantly grown on soils with a lower clay content than Andelst which has about 30% clay (the clay content is the most important factor driving the preferential flow in GeoPEARL). In 2015, it was decided not to include the drainpipe at all, based on the assumption that spray drift would dominate anyhow (with the caveats that in parallel supporting calculations should be done on the drainpipe contribution based on fruit-crop simulations of GeoPEARL and on the spray drift contribution based on DRT99, i.e. Drift-Reducing Technology with 99% reduction). Hereafter, it was shown that the drainpipe contribution could not be ignored for this type of spray techniques with a high level of drift reduction (see Boesten et al., 2018). Boesten et al. (2018) propose to include the drainpipe contribution while making use of the approach followed by Tiktak et al. (2012b) and hence use the Andelst drainpipe scenario for assessing the contribution of the drainpipe.

Tiktak et al. (2012a) included atmospheric deposition in the *d-fi* scenario by using conservative default values for this deposition based on the vapour pressure of the substance as recommended by FOCUS (2008). Example calculations for four substances showed that atmospheric deposition was the main exposure route for one of these substances for DRT95 (see their Figure 64 on p. 103). The difference in the level of sophistication between spray drift and drainpipe leaching on the one hand and atmospheric deposition on the other hand in the approach by Tiktak et al. (2012a) is large. Boesten et al. (2018) considered it difficult to justify to combine a very sophisticated probabilistic approach for spray drift with a simplistic conservative approach for atmospheric deposition and recommended to exclude the entry route atmospheric deposition from the scenarios until a more sophisticated methodology becomes available. Furthermore, Boesten et al. (2018) analysed the possible contribution of atmospheric deposition as compared to spray drift. The results, which are given also in Annex 1 of this report, indicate that atmospheric deposition cannot be ignored in this exposure assessment of aquatic organisms after spray applications in Dutch fruit crops.

The working group reconsidered this viewpoint, and given the situation that atmospheric deposition cannot be ignored, it was recommended to use as a first tier the conservative default values analogous to the approach by Tiktak et al. (2012a) and to develop a more sophisticated approach at a later stage. The recommendation was accepted by the Dutch ministries.

In this report the developed scenario for spray drift deposition is described as well as the approach for the contribution of the drainpipe and for atmospheric deposition. Direct leaching of groundwater to the ditch is included via the drain emission, runoff is not considered.

1.4 Structure of the report

Chapter 2 gives some specific considerations relevant for fruit orchards in the Netherlands. The spray drift scenario selection and parameterisation is discussed in Chapter 3, followed by a discussion on the approach taken for the drain pipe scenario in Chapter 4 and specific aspects of the combination of both scenarios into one scenario. In Chapter 5 the parameterisation of the receiving ditch is discussed. This chapter is a summary of the more elaborated report on the hydrology in Ter Horst et al. (2020). Example calculations are described and discussed in Chapter 6. In Chapter 7 the parameterisation of the atmospheric deposition is discussed. It was decided at a late stage in the development of the fruit orchard scenarios to add atmospheric deposition as one of the emission routes. Therefore, the parameterisation of this route is described in one of the last chapters in the report. Chapter 8 and 9 are dedicated to discussion and conclusions and recommendations, respectively.

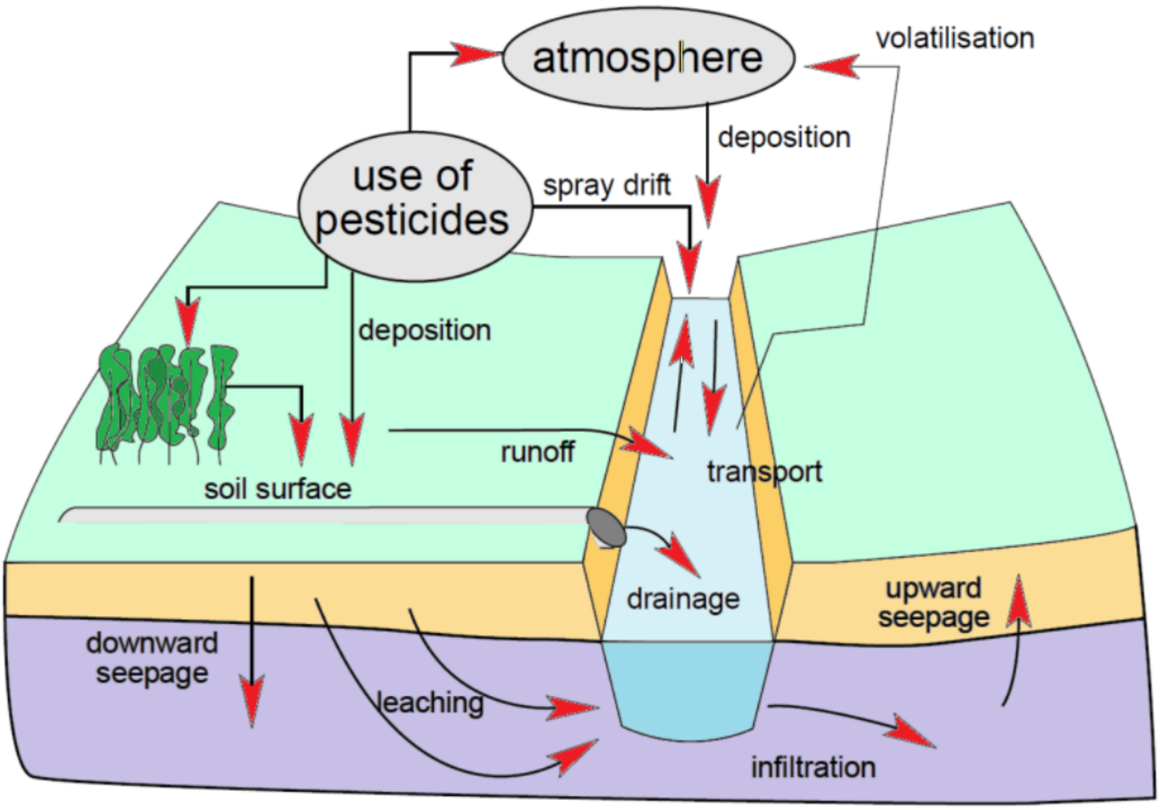

Figure 2 *Entry routes to nearby surface waters after a spray application.*

2 Fruit orchard management aspects

2.1 Fruit orchards in the Netherlands

Fruit crops are grown in specific areas in the Netherlands. The total area is about 19.770 ha of which the main fruit crops are apple and pear. Fruit crop growing is especially concentrated in the areas Betuwe/ the Rivierenland area, Zeeland, West-Friesland, South-Limburg, Flevoland and the Noordoostpolder (Van de Zande et al. 2019).

2.2 Drainage and irrigation practices

Fruit orchards require a controlled groundwater level. Most of the fruit orchards in the Netherlands are therefore drained while using tube drainage, whereby the drainpipes lay between 80 cm and 120 cm below soil surface. Drained orchards can be found specifically in the Flevoland and the Noordoostpolder. The Betuwe area has less fruit orchards with drained fields. Calculations based on the spatially distributed fate model GeoPEARL show that around 78 percent of the Dutch fruit orchards are drained[4] (see Chapter 4 of this report).

For optimal yield of apples and pears Dutch farmers supply additional water by drip irrigation to avoid moisture stress. About 75% of Dutch fruit growers have irrigation systems in place for drip irrigation. Bal and Verhage (2011) indicated that the annual water need is between 36 – 147 mm (based on the total surface area of the orchard). In an average year the annual irrigation is typically 110 mm (personal communication M.P. van der Maas, 2019) which is added to the annual precipitation which is around 790 mm in the Netherlands. The irrigation is applied only to the tree strip which receives an annual irrigation of 330 mm whereas the grass strip between the tree rows is not irrigated. In addition to drip irrigation, water is supplied by sprinkler irrigation in case of night frost during the blooming period. According to Van der Maas (personal communication, 2020) this happens in 50% of the years with an average of three irrigations in the years that night frost occurs. About 20 mm is supplied per night.

2.3 Handling of spray drift emission reduction measures

Reduction of spray drift deposition on nearby surface water by special application techniques or introduction due to a crop-free buffer zone is an essential element of the regulatory exposure assessment. The assessment is based on the so-called drift-reduction matrix shown in Figure 5. So a farmer or company can choose between combinations of a certain drift reduction technology class (DRT class) and a crop-free buffer zone (cfbz). The minimal agronomic crop-free zone is defined as the distance between the centre of the last tree row and the top of the ditch bank; this agronomic minimum for fruit orchards is 3 m (see Figure 3).

[4] The presence of drain tubes in GeoPEARL is based on expert knowledge (Tiktak et al. 2003).

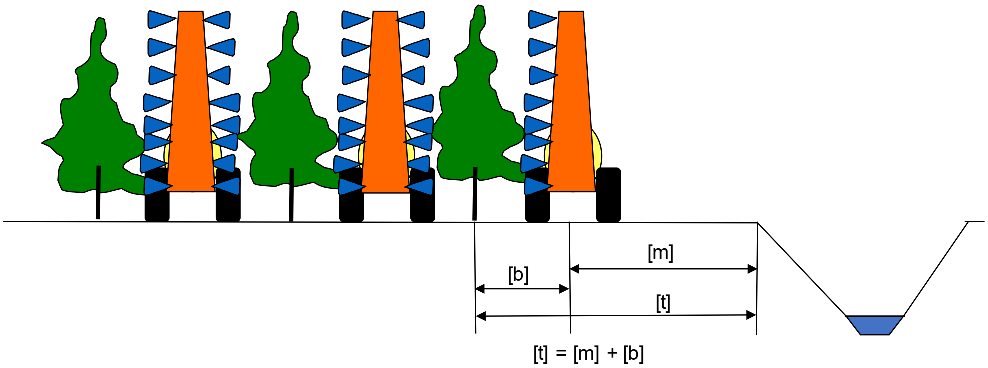

Figure 3 *Schematic representation of the orchard layout for sideways and upward spray applications. The total crop free zone [t] equals the sum of the minimal agronomic crop free zone [m] and the crop free buffer zone [b] (from van de Zande et al., 2019).*

For sideways and upward spraying in Dutch fruit crops the following DRT classes are identified: DRT50, DRT75, DRT90, DRT95, DRT97.5 and DRT99. The Environmental Activity Decree (MinI&W, 2021) states that DRT75 and DRT90 are the minimum allowed spray drift reducing techniques (DRT75 can only be used for a crop-free buffer zone of at least 4.5 m). DRT95 is frequently used (some 40% of the applications) and DRT97.5 and DRT99 are less common.

The classification of the reduction classes is based on spray applications in the full-leaf situation of the fruit trees and on the geometry and distance to the tree rows of a fixed and standardized ditch and on the definitions for the drift reduction classification of spray techniques following ISO22369 and the Dutch protocol (TCT, 2017a, 2017b). This standardized ditch was adopted from the currently used evaluation ditch for the risk assessment in the Netherlands. Note that the spray drift reduction may vary dependent on the distance to the last tree row, as shown in Figure 4. For more information on spray drift measurements and the spray drift model used in this report we refer to Van de Zande et al. (2019) and Holterman et al. (2021), respectively.

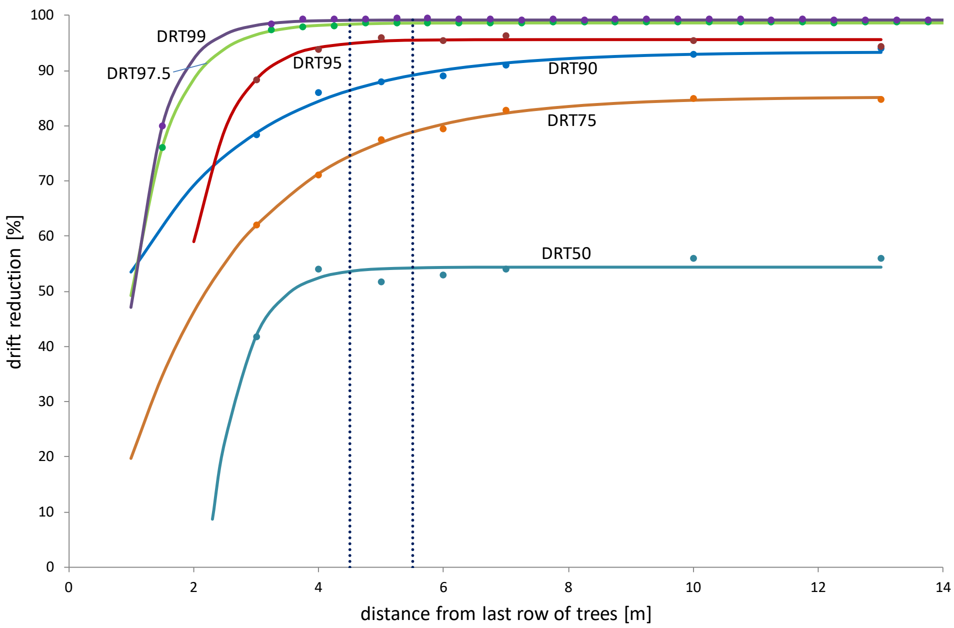

Figure 4 *Spray drift reduction as a function of downwind distance from last tree row, compared to drift deposits for a standard application at the corresponding distance for fruit orchards in full leaf. According to the Dutch TCT protocol drift reduction classes are defined by the reduction level at the location of the water surface for a standardized ditch and a cross wind. For fruit orchards this evaluation zone is located 4.5-5.5 m from the last tree row (dashed zone). Dots: measured spray drift reductions, solid lines: best fitting reduction curves (from Holterman et al., 2018).*

So for the development of the exposure assessment it was required that the user/notifier should be able to select one of the options shown in Figure 5.

Crop-free buffer zone (m)	0	1	2	3	4	5	6	7	8	9
Crop-free zone (m)	3	4	5	6	7	8	9	10	11	12
DRT75										
DRT90										
DRT95										
DRT97.5										
DRT99										

Figure 5 *The drift-reduction matrix consisting of rows for the DRT-options and of columns for the options for the widths of the crop-free zones. The empty cells are all possible combinations. The grey cells indicate combinations that are considered unacceptable by the Dutch regulation (Environmental Activity Decree, MinI&W, 2021).*

2.4 Estimation of the application dates

The date of application may have a large effect on the outcome of the exposure assessment. For example, spray drift deposition depends strongly on the crop development stage, but also drainpipe emission is depends on the date of application.

For pesticides applied in Dutch fruit crops, the label specifies usually the crop phenology development stage in terms of the BBCH (BBCH, 2001). We considered it therefore appropriate to base the application date on the BBCH codes (or the BBCH range). The consequence is that the exposure assessment methodology requires an established relationship between the BBCH development stages and calendar dates.

We used one relationship between BBCH code and calendar date for all simulation years in the scenario. The applied relationship is based on experimental data for different apple varieties which were measured between 1999 and 2010 (see Table 7 and 8 in Van de Zande et al., 2019, and Annex 3 in Holterman et al. 2018). In principle it would be more accurate to differentiate between years (and crop types) e.g. based on the temperature sum (so faster crop development in warmer years). Given the limited data that can underpin such differentiation, an averaged relationship is used, which is considered generic for all weather years.

2.5 Spray application schemes

Apples and pears are by far the most abundant fruit crops in the Netherlands (about 6500 ha apples and 10000 ha pears, together covering 85% of the surface area of Dutch fruit crops in 2019, CBS 2021). The typical application schemes for apple and pear in the Netherlands (Figure 6) show that (i) most pesticides are applied (via upward and sideways spraying) once per year, (ii) a few pesticides are applied 2-3 times and (iii) captan is applied 14-15 times. Note that this application scheme is from 2015, some of the active ingredients may not be available anymore.

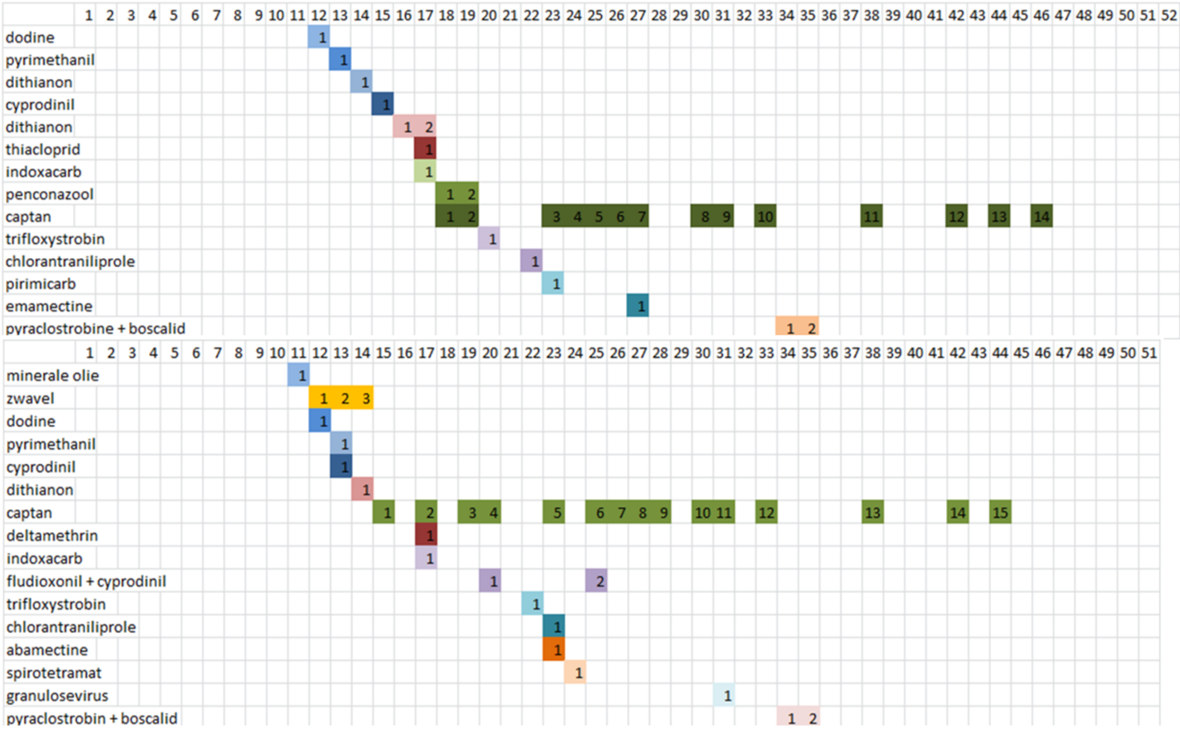

Figure 6 *Typical application schemes for apple (top) and pear (bottom) in the Netherlands. The columns are week numbers and each coloured cell is an application.*

3 Selection and parameterisation of the spray drift scenario

3.1 Followed approach

Based on the exposure assessment goal, the aim is to select a time-location combination from the STPC (i.e. the calculated concentration that gives the 90^{th} overall percentile of the PEC_{max}). The best approach would be to build a spatially-distributed model for exposure in surface water based on the detailed surface water model TOXSWA and a probabilistic spray drift model based on the SPEXUS model for different DRT-class application techniques and different distances of the crop-free buffer zone (so following an approach similar to GeoPEARL). However, this would require a model parameterisation for thousands of locations. This is not yet feasible. Therefore, a more pragmatic approach was adopted similar to that for the *d-fi* scenario (Van de Zande et al., 2012; Holterman et al. 2021).

This approach consisted of the following steps:

1. development of a sophisticated local spray drift deposition model SPEXUS based on a combination of physical concepts and empirical data (section 3.2)
2. combination of this model with a simple metamodel of TOXSWA for linking spray drift depositions to concentrations (section 3.3)
3. development of a spatially distributed probabilistic model (proSPEXUS) for exposure concentrations based on spray drift input only, using all relevant Dutch GIS information currently available and based on the combination of the local spray drift model and the TOXSWA metamodel (section 3.4.1)
4. simulations with this spatially distributed model to generate STPCs that can be used to select a single ditch-orchard combination which can generate the desired 90th percentile of this STPC (section 3.4.2)
5. more detailed simulations with this model to assess the Temporal Percentile (TPC) for this single ditch-orchard system and assessment of the percentile of this TPC that corresponds with the 90th percentile of the STPC, which is called 'the required temporal percentile' in the last step of this list (section 3.4.2)
6. using the TPC to generate time series of spray drift depositions to be used for multi-year simulations with TOXSWA (section 3.5)
7. parameterisation of TOXSWA for this single ditch-orchard system for a time series of 20 years, of which 5 years are warming up years (Chapter 5)

In the next sections the main elements of this approach are briefly described. We refer to Holterman et al (2017, 2018, 2021) for further detail on the SPEXUS drift model and the spatially distributed model.

3.2 The local model SPEXUS for spray drift deposition

The local model, SPEXUS, (Holterman et al. 2017; 2018) was developed based on measurements of 316 deposition-distance curves (5456 deposit values) for apple tree orchards in the Netherlands (Van de Zande et al., 2019). The model computes downwind spray drift deposits as an exponential decay function of the distance between the last tree row and the ditch. The spray drift is a function of environmental parameters: wind speed, air temperature and wind direction. Other factors of importance include orchard size and canopy density (so crop development, described in terms of the BBCH), sprayer fan speed and application technique (DRT class). Figure 7 gives an example of downwind deposition curves computed by the SPEXUS drift model, showing the effect of average wind speeds.

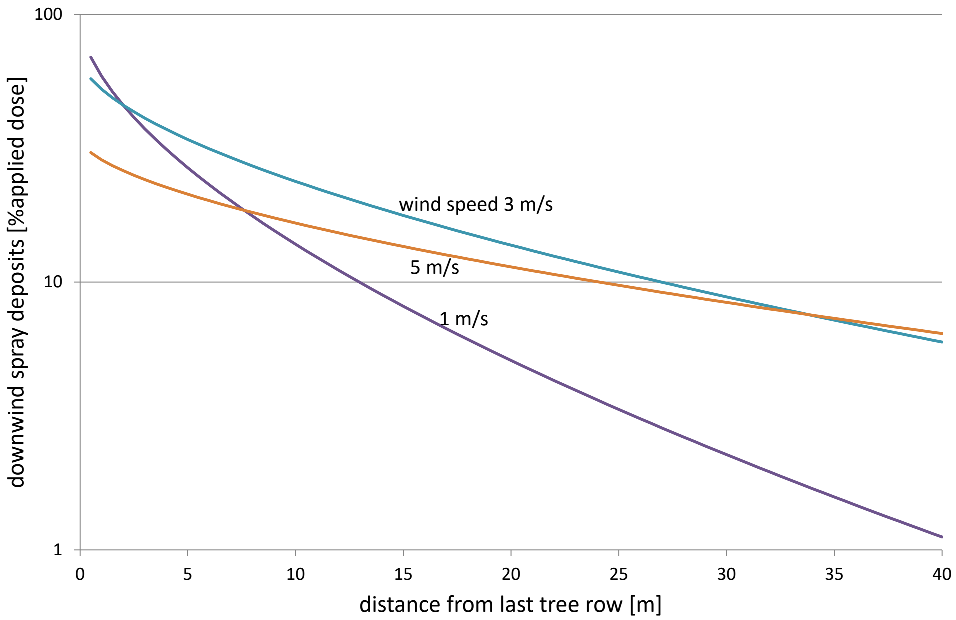

Figure 7 *Example of downwind spray deposits as a function of distance from the last tree row, for three wind speeds (temperature 15°C, BBCH 70, conventional spray application, high fan speed)(from Holterman et al., 2018).*

3.3 The TOXSWA metamodel for spray drift input

Exposure concentrations in the ditch were derived from the spray drift deposition with a metamodel of TOXSWA which was based on the assumption that the increase in the concentration by a spray drift event is simply the spray drift deposition divided by the average water depth of the ditch. The metamodel accounts for the slope of the sides of the water body. As described in Section 1.2, the Ecologically Relevant Concentration (ERC) is the dissolved concentration in the water phase averaged over 100 m of ditch length. In case of repeated applications within one calendar year, the metamodel has two extreme options: (1) a decline that is so fast that the concentration decreases to zero well before the next application takes place and (2) no decline at all, which has the consequence that the concentrations of the different spray drift events sum up (see Figure 8).

Note that the annual maximum concentration, the PEC_{max} is used in the scenario selection procedure.

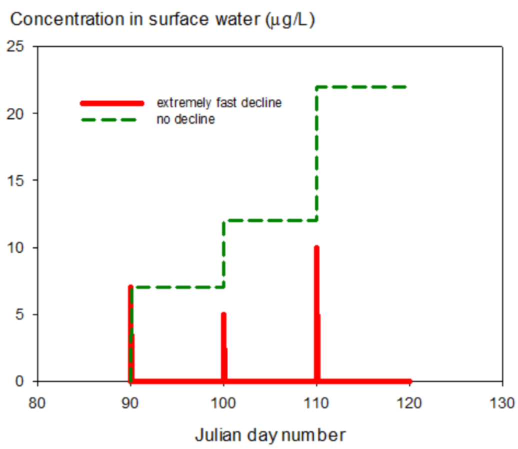

Figure 8 *Concentration in surface water as a function of time as calculated with the TOXSWA metamodel considering three spray drift events that increase the concentration by 7, 5 and 10 µg/L. The solid line is the concentration based on the assumption of extremely fast decline and the dashed line is based on no decline between the applications.*

3.4 Geographically distributed spray drift model proSPEXUS

3.4.1 Geographical aspects of the modelling approach

The areas in which fruit orchards are grown may differ considerably with respect to water body types, orchard orientation and weather conditions. The following databases formed the basis of the geographically distributed spray drift model:

- spatial database of Dutch ditches based on the TOP10 vector map of water courses in the Netherlands, consisting of 66 different 'hydrotypes' including a description of their geometry (e.g. water depth in winter); see Massop et al. (2006)
- spatial database of differences in water depth of the ditches between winter and summer (divided into 9 classes)
- frequency distributions of the N-E-S-W orientation of the tree rows of fruit crops (divided into 18 classes) for different meteorological districts in the Netherlands
- hourly 20-year time series of meteorological data of 14 Dutch weather stations (wind speed, wind direction, air temperature, relative air humidity)
- the LGN land use map (LGN6, Hazeu et al. 2010) indicating the areas where fruit crops are grown with a resolution of 25×25 m.

The total lengths of ditches adjacent to fruit crops were determined using the TOP10 vector map of water courses in the Netherlands combined with the LGN land use map based on the criterion that the distance between the water course and the field with the fruit crop (orchard) should be less than 10 m.

Although the Netherlands is a relatively small country, weather conditions may differ between regions. Therefore, the Netherlands were divided into 14 meteorological districts each with a representative KNMI weather station. From the hourly data on wind speed and wind direction frequency distributions were made for each district. Only daylight values of wind speed and wind direction were included in the population because spraying during the night is unlikely; wind speeds above 5 m/s were not included as well because spraying at such wind speeds is no good agricultural practice (MinI&W, 2021). The simulations were based on these frequency distributions, so the 20-year weather time series were not used as such. Also for the temperature frequency distributions were made. Hourly averaged values were taken and transferred to a weekly distribution pattern.

The lengths of the different ditch hydrotypes adjacent to fruit crops were calculated for each meteorological district. Only the so-called primary and secondary ditches were considered; the so-called tertiary ditches were excluded because most of them do not carry water permanently. So only 44 of the in total 66 different hydrotypes were included in the model. The total ditch length for each hydrotype was divided into four equal parts which each corresponded with one side of the orchard (see Figure 9). The spray drift deposition for these four types of orientation differed: for ditch types 2 and 4 the standard minimum crop-free zone of 3 m was used and for ditch types 1 and 3 this zone was set at 6 m (to mimic the procedure that the farmer turns his tractor and spraying machinery at the end of each tree row).

So, there were 14 meteo-districts, 18 classes of orientation of the tree rows (in total 180˚), 44 hydrotypes, 9 classes of differences between winter and summer water level, and 4 types of ditch orientations. This gives 14 × 18 × 44 × 9 × 4 = 399 168 combinations. However, most of these combinations do not occur, and we ended up with about 74,000 combinations, which are the spatial units (SUs). Simulations were made for 100 'stochastic years' for each SU and concentrations in the surface water were calculated to achieve sufficient accuracy.

Thus, the geographically distributed spray drift model (proSPEXUS) simulates the concentration in all possible ditches adjacent to fruit crops for the entire area of the Netherlands using 74,000 SUs and 100 'stochastic years'.

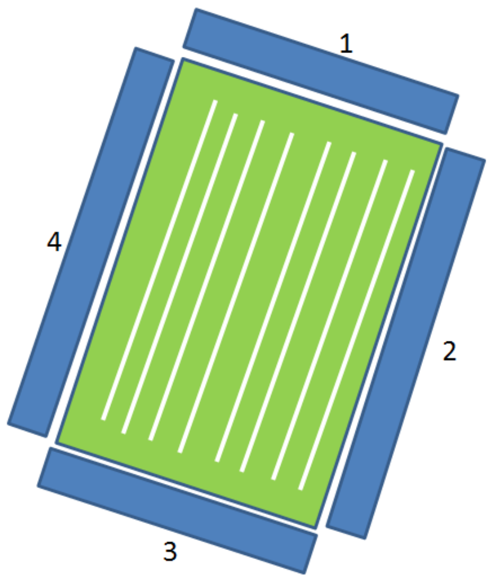

Figure 9 *Schematic representation of the distribution of the ditches over the four sides of the orchard. The line segments indicate the direction of the tree rows. It is assumed that all sides have equal length so it would have been more appropriate to represent the orchard as a square instead of a rectangle.*

3.4.2 Simulation procedure

The intention of the methodology was to have one single ditch-orchard scenario that can be run for any substance and any application scheme. It is impossible to perform calculations of the spatio-temporal population of concentrations (STPC) for all possible combinations of application times (see Figure 6). So, it was decided to calculate STPCs for 1, 3 or 15 applications per year. This selection was based on the commonly used application schemes in apple and pear (see Section 2.3). For 1 and 3 applications, both 'early' and 'late' applications were simulated (see Table 1 for the overview of considered application schemes and application dates).

During the development of the exposure assessment methodology, it became clear that the residence times of water in the ditch of the selected scenario are so short that significant accumulation of concentrations due to repeated applications is unlikely to occur (see section 5.5). Therefore, the STPCs were calculated only for the fast-decline option in the metamodel. Thus there remain five options for calculating the STPC as shown in Table 1 (E1-L1-E3f-L3f-S15f) and these will be further called 'the basic application schemes'.

The scenario selection procedure consisted of two steps. The first step was to generate cumulative frequency distributions (abbreviated '*cfd*') of the STPC for (i) each of the basic application schemes E1-L1-E3f-L3f-S15f, (ii) each of the DRT classes (conventional-50-75-90-95-97½-99), and (iii) each of the widths of the crop-free buffer zones (0-9 m). The selected crop-free buffer zone[5] was added alongside as well as to the headland. The consequences of the latter assumption is discussed in Section 8.3. So, in total 5×7×10= 350 *cfd*-curves were derived[6]. The exposure assessment goal for each combination of basic application scheme, DRT class and width of the crop-free buffer zone (further called '*bas-DRT-w* combination') was the 90th percentile derived from the STPC.

[5] The total crop-free zone is considered to be the sum of the minimal agronomic crop-free zone and the crop-free buffer zone.
[6] As of January 1, 2021 (MinI&W, 2021) for all crops a spray application must be at least DRT75, so the conventional and DRT50 applications are not allowed anymore for the Dutch situation.

Table 1 *Overview of the basic application schemes and their characteristics. The 'f' in the acronym stands for 'fast', indicating that the concentration was calculated assuming fast dissipation between the application dates, so assuming no accumulation.*

acronym of application scheme	E1	L1	E3f	L3f	S15f
number of applications	1	1	3	3	15
application season	early	late	early	late	full season
application dates in simulations for full spatio-temporal population of concentrations	4 May	29 Aug.	4 May 11 May 18 May	29 Aug. 5 Sept. 12 Sept.	17 June 24 June …. 16 Sept. 23 Sept.
ranges of week numbers represented by basic application schemes	1-22 45-52	23-44	1-22 45-52	23-44	

Figure 10 shows the *cfd* curves for all basic application schemes in combination with a zero crop-free buffer zone and DRT90 as an example. The curves for E1 and L1 have about 50% zero values caused by wind directions from the ditch to the field during spraying (that is, the ditch is on the upwind side of the field). Curve E1 shows higher PEC values than curve L1 as expected because when spraying bare trees, the spray drift is higher than that when spraying onto trees in full leaf. The lines for three applications (E3f and L3f) show about 15% zero values; this is understandable because the likelihood that three applications give zero values is about $0.5^3 = 0.125$, so 12.5%. In case of the 15 applications it is of course extremely unlikely that the maximum of the 15 drift events is zero and it is understandable that the shape of the *cfd* curve approaches the shape of a normal distribution.

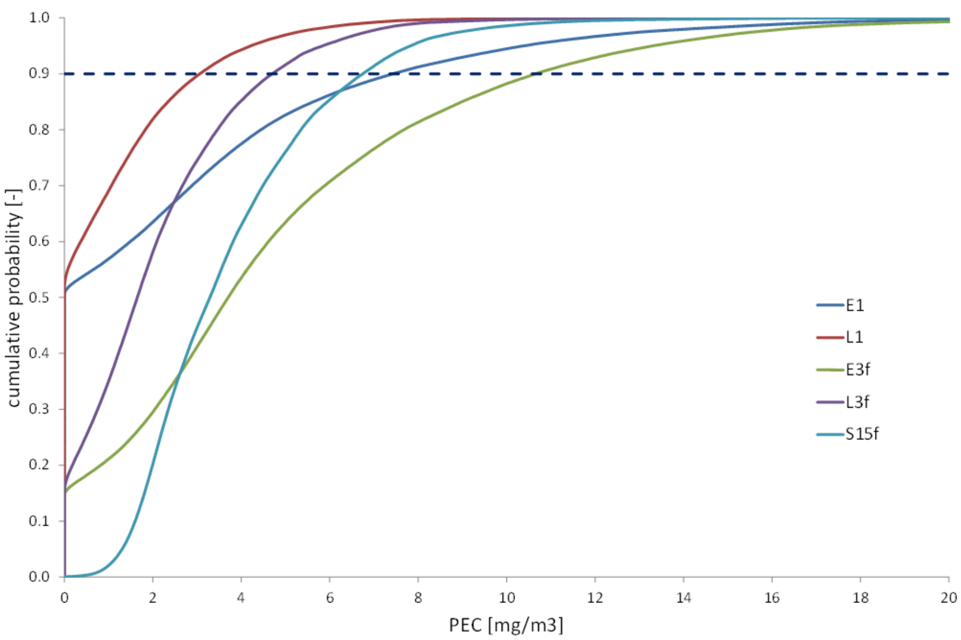

Figure 10 *The cfd curves of the STPC of all five basic application schemes as indicated for DRT90 and a zero crop-free buffer zone. PEC refers to the annual maximum concentration.*

The aim was to have at the end one single SU (spatial unit, i.e. spatial configuration) that could form the basis for exposure calculations for all these considered combinations. Each combination will have its own time percentile at this one SU corresponding with the overall 90th percentile PEC_{max} of this combination. To achieve this goal, all time-space combinations that were in the range between the 87th and 93rd percentile for each *bas-DRT-w* combination were combined and a suitable single SU was selected to be used for each *bas-DRT-w* combination. The selection procedure is described in detail in Holterman et al. (2021). As a final step, TOXSWA was fully parameterised for this SU (Chapter 5). Because the scenario calculations at the end will be for a limited number of years, in view of the robustness of the scenario it was the intention to select a SU with preferably a time percentile close to the median. The background of this is that the error in the estimated median from a limited sample population is smaller than the error in an extremer percentile (e.g. the 80th).

Other criteria relevant for the selection of the SU were that the selected configuration preferably is situated in a relevant fruit growing region and that the water body type and orchard orientation are frequently occurring.

3.4.3 Selected spatial unit and corresponding temporal percentiles

The finally selected SU (used for all 350 *bas-DRT-w* combinations) had the following properties (Holterman et al., 2021):

- Ditch with hydrotype 'Betuwe stroomruggrond' (secondary ditch, code 601002), a water level of 30 cm both in winter (October to March) and in summer (April to September), a width of the water surface of 234 cm and a width of the bottom of the ditch of 174 cm.
- Ditch at the east side of the orchard (parallel to the direction of the trees)
- Direction of the tree rows was 20° to the west of the north direction (degrees based on 360° for full north-east-south-west circle, see Figure 11)
- Meteorological district Herwijnen in the hydrological district Rivierenland.

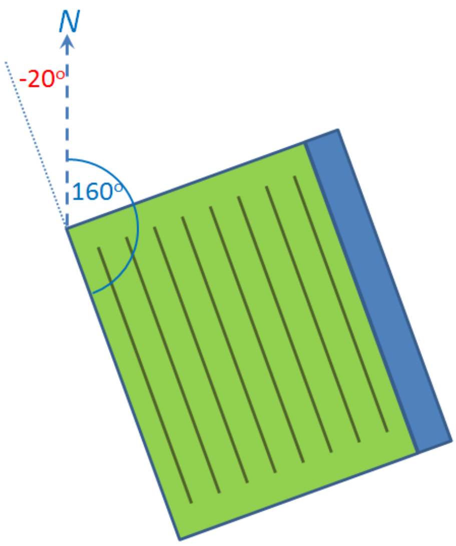

Figure 11 *Orientation of selected SU. The green part is the orchard and the blue part is the ditch. The line segments indicate the direction of the tree rows.*

The second step of the simulations was as follows. For each of the 350 combinations, stochastic simulations were carried out for this selected SU for 10 000 stochastic years, thus generating the concentration profile (i.e list of annual maximum concentrations, the TPC) for this selected SU.

Figure 12 shows as an example the *cfd* curves of the TPCs for DRT90 and a zero buffer zone. Now the curves for E1 and L1 show some 37% zero values, so less than 50%. This is the consequence of the orientation of the selected ditch (Figure 11) which is more often on the downwind side due to the dominant SW wind direction in the Netherlands. The curves for E1 and L1 are approximately straight lines, which indicates that these distributions are approximately uniform. The shape of the curve for S15f is now close to a normal distribution.

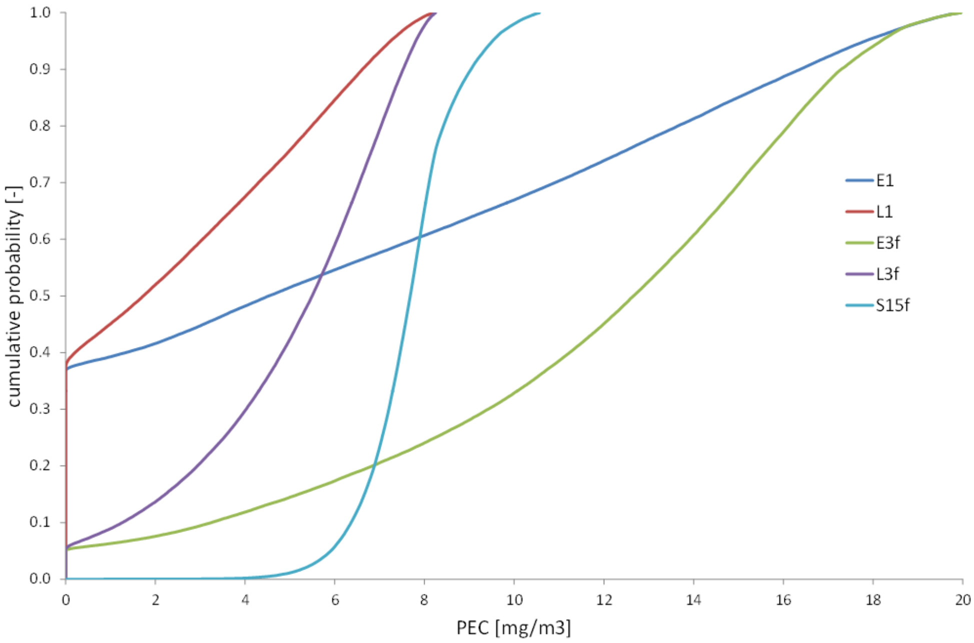

Figure 12 *The cfd curves of the concentration profiles TPC for the selected configuration (SU) of all five basic application schemes and for DRT90 and a zero buffer zone. PEC refers to the annual maximum concentrations.*

Thus, we have a cumulative frequency distribution (*cfd)* of the STPC (countrywide) and a *cfd* of the TPC of the selected SU for all these 350 *bas-DRT-w* combinations. These were used to derive the required temporal percentile of the selected SU corresponding with the overall 90th percentile from the STPC. This was done as shown in Figure 13: from the STPC the concentration was derived which corresponds to the overall 90th percentile PEC value ('P90' in the figure) and this was used to determine the corresponding temporal percentile of the TPC ('T90' in the figure). Thus for each basic scenario we now know the required temporal percentile that will give the overall 90th percentile.

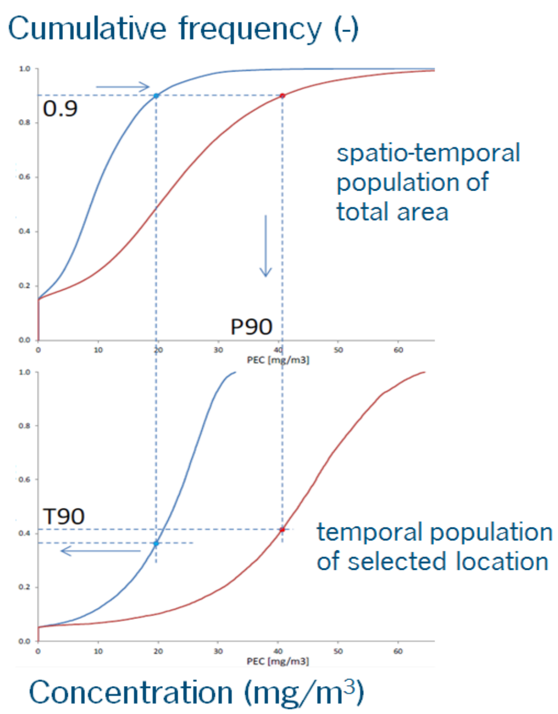

Figure 13 *Illustration of procedure to estimate the time percentile of the exposure concentration from the combination of the cumulative frequency distributions of (i) the STPC and (ii) the local TPC (of the selected SU). The red and blue lines are cfds for two different* bas-DRT-w *combinations.*

The temporal percentiles for the different combinations of application schemes, DRT classes and crop-free buffer zones ranged between 10 and 70% but were mostly between 40 and 60% (Figure 14).

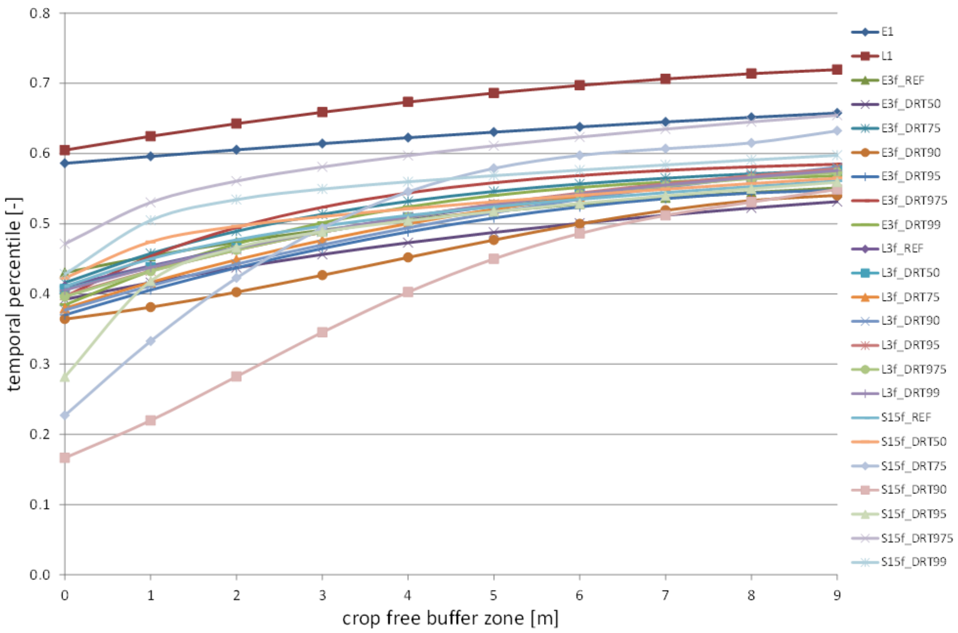

Figure 14 *Temporal percentile for the selected spatial unit (SU) corresponding to an overall 90th percentile as a function of the width of the crop-free buffer zone. The 23 lines shown are for the different combinations of application schemes (L1, E1, L3f, E3f, S15f) and DRT classes (0-50-75-90-97½-99). For E1 and L1 the differences in temporal percentile between different application techniques is negligible. Therefore only one curve suffices for E1 and L1 application schemes.*

3.5 Parameterisation of non-basic exposure combinations

The parameterisation of the drift scenario model requires several aspects to be accounted for. The basic combinations cover 350 cases (Section 3.4) each with its own temporal percentile of the TPC. However, in practice much more combinations can occur that are not covered by the basic combinations. For instance, the number of spray applications may be different from 1, 3 or 15. Additionally, the application dates may be different from the selected dates for early and late basic scenarios (Table 1). Thirdly, with multiple applications, the application techniques may be different to cope with a changing canopy density throughout the season. These aspects require an adjusted procedure for parameterisation.

The procedure for non-basic application- DRT class and crop-free bufferzone combinations is described in detail in Holterman et al. (2021). We give here a short summary of the approach. For the selected SU, *cfd*s are determined for a single application for each week of the year (52), each application technique (7) and each crop-free zone (10). Thus, a set of 3640 *cfd*s is predetermined representing all possible single spray applications. Any real combination consists of one or more of these single applications (with intervals of at least one week). For fast dissipating substances, the *cfd* of any real scenario can be constructed from the *cfd*s of the single applications (Holterman et al. 2021).

Although in this way a *cfd* for any real scenario can be obtained, it is still unknown which temporal percentile is appropriate. Predefined temporal percentiles are only available for the 350 basic combinations. In principle, for the real scenario the most resembling basic scenario can be selected and the corresponding temporal percentile can be used as an estimate of the temporal percentile for the real scenario. In many cases two (or few more) basic combinations may be close. In those cases an appropriate interpolation of corresponding temporal percentiles is useful. If the number of spray applications is 2 or in the range 4 through 14, a (linear) interpolation procedure gives a good estimate of the temporal percentile to be used for the real scenario (see Figure 15 as an example). Additionally, the various spray applications in a year may involve different application techniques, representing different temporal percentiles. To be on the safe side, typically the highest temporal percentile is selected when different techniques are involved.

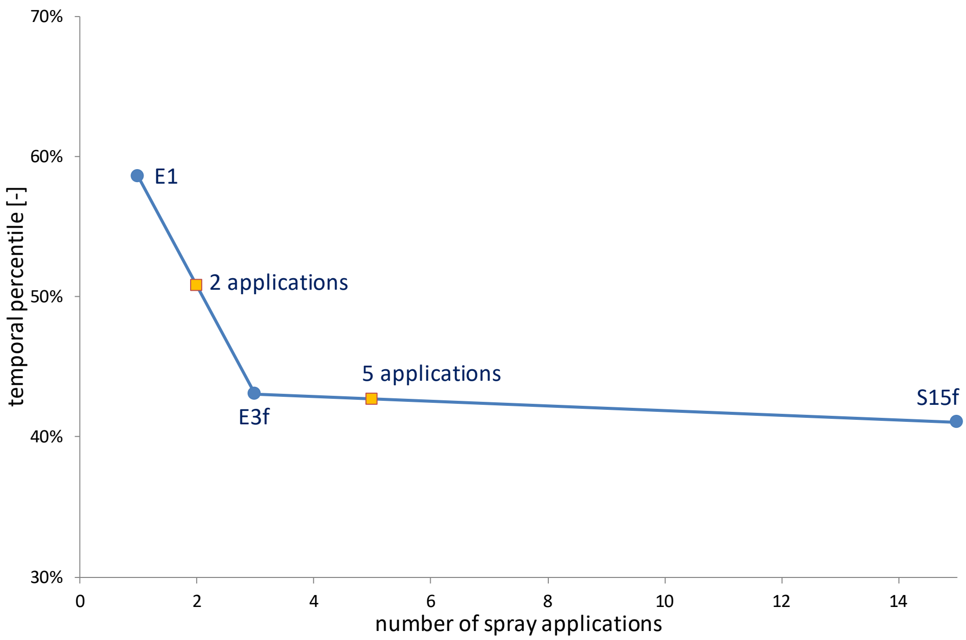

Figure 15 *Example of linear interpolation of the temporal percentile for different numbers of spray applications (standard application technique, no crop-free buffer zone).*

3.6 Use of the STPC and the TPC to parameterise the exposure scenario

For each exposure assessment, we have now the appropriate *cfd* of the TPC and the required temporal percentile for all possible combinations of application techniques and crop-free buffer zones. TOXSWA was parameterised for this ditch-orchard system to run for 20 years (1986-2005) of which the first 5 are warming-up years and the last 15 are used as assessment years for the calculation of the exposure endpoint. TOXSWA requires spray drift deposition values as input, for the 20 years mentioned above.

Ideally, drift deposition data are computed by the SPEXUS model using the actual weather data on the days of application throughout these 20 years. However, statistically the number of 20 years (or even 15 years for the assessment) is too small to obtain a sample distribution that is representative of the true TPC[7]. Therefore, drift deposits were selected from the TPC using the corresponding *cfd* of the selected SU. As this *cfd* is based on a large number of stochastic years, it accurately describes the population of average drift deposits.

In an *N* year simulation scenario, *N* PEC_{max} values are obtained, derived from *N* drift deposits leading to these PEC_{max} values. Selecting drift deposits for the local SU for 15 assessment years is mathematically equivalent to randomly drawing 15 times from the corresponding *cfd*. The drawing takes place as follows. Since each year is independent of all other years, the results for all years are

[7] We tested first the alternative to calculate the spray drift with the local spray drift model using the weather data in the hour of application but this resulted in far too large differences between the sample distribution of these 20 draws and the 'true' TPC, hence this approach did not lead to a robust concentration estimate.

equally likely. Therefore, the y axis (cumulative probability) of the *cfd* can be divided in *N* equidistant steps. Then, the centre of the *i*-th step on the ordinate is given by the following equation:

$$p_i = 100 \frac{i - \frac{1}{2}}{N} \text{ [\%]} \qquad (1)$$

where p_i is the percentile of rank number *i* (see Appendix 13 of FOCUS, 2009). Next, the spray drift deposits are derived from the *cfd* by selecting values on the x axis corresponding to the p_i values; see Figure 16. The allocation of the percentiles to the different years was done by a procedure based on the actual weather conditions on the day of application to reflect a more natural (quasi random) sequence of drift deposits throughout these years. The spray drift deposits of the 5 warming-up years were picked in a similar procedure, with *N*=5.

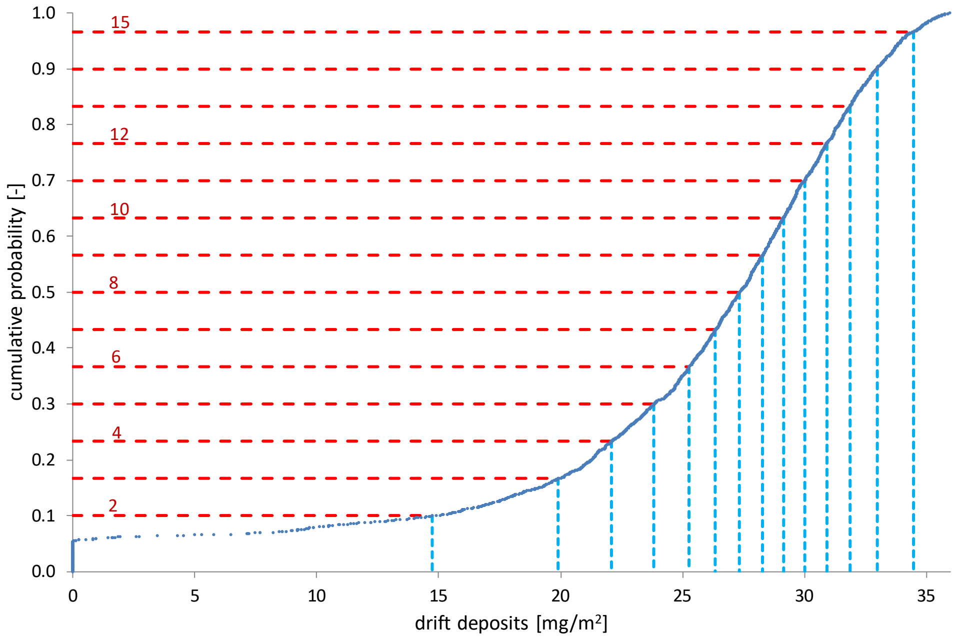

Figure 16 *Selecting equally likely drift deposits from the local cfd for 15 assessment years (E3f scenario; no crop-free buffer zone).*

The example of Figure 17 shows how using actual weather data leads to PEC_{max} values that differ from the multi-year distribution. The yellow dots in the graph correspond to the drift values of Figure 16, and are used as the PEC_{max} values in the risk assessment.

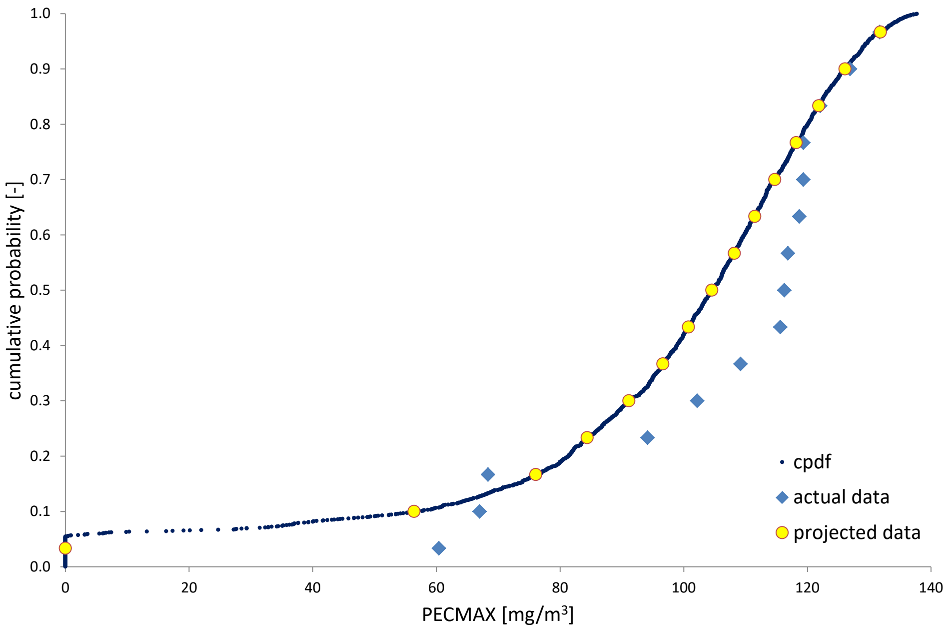

Figure 17 *Example of selected PEC_{max} values based on actual weather data (blue diamonds) and using the 'true' TPC (yellow dots) (E3f scenario, no crop-free buffer zone).*

So, the TOXSWA output consists of 15 annual maximum concentrations. The required temporal percentile (mentioned at the start of this section) depends on the scenario and is derived from a precomputed list of values, using the procedure described in Sections 3.4 and 3.5. The temporal percentile is an input parameter for TOXSWA and TOXSWA subsequently selects the exposure concentration from the *cfd* of these 15 concentrations by taking the cumulative percentile p_i closest to the required temporal percentile. The index *i* then also indicates the corresponding PEC_{max} and the year where this PEC_{max} occurs[8].

The above procedure for estimating spray drift based on the 'true' TPC is implemented in the xSPEXUS model and has the advantage that drift is not influenced by the weather conditions at the hour of application (see Figure 17). So extreme weather conditions at a certain moment will not have any effect on the drift estimates. This leads to a more robust time series of the annual maximum concentrations in TOXSWA.

As a test of the parameterised spray drift deposition model xSPEXUS for the selected ditch-orchard combination, simulations were made for a single application on all calendar days of the year for three DRT classes. Figure 18 shows the drift deposits as a function of the day of application, these deposits on the local ditch correspond to the countrywide PEC90 value. The results in Figure 18 show that there is a gradual course of the depositions as a function of the application time. The spray drift deposition is lowest in summer when the trees are in full leaf. One would expect that DRT99 would give a deposition that is ten times smaller than DRT90. This is indeed the case in summer but in winter the difference is about a factor 4-5. Usually, in winter drift reducing techniques are less effective than in summer. Consequently, the differences between DRT90 and DRT99 are less in winter than in summer.

[8] Note that this procedure is for spray drift only. In Chapter 4 emission from drainpipes is included to the scenario and also the impact on the selection of the temporal percentile will be discussed.

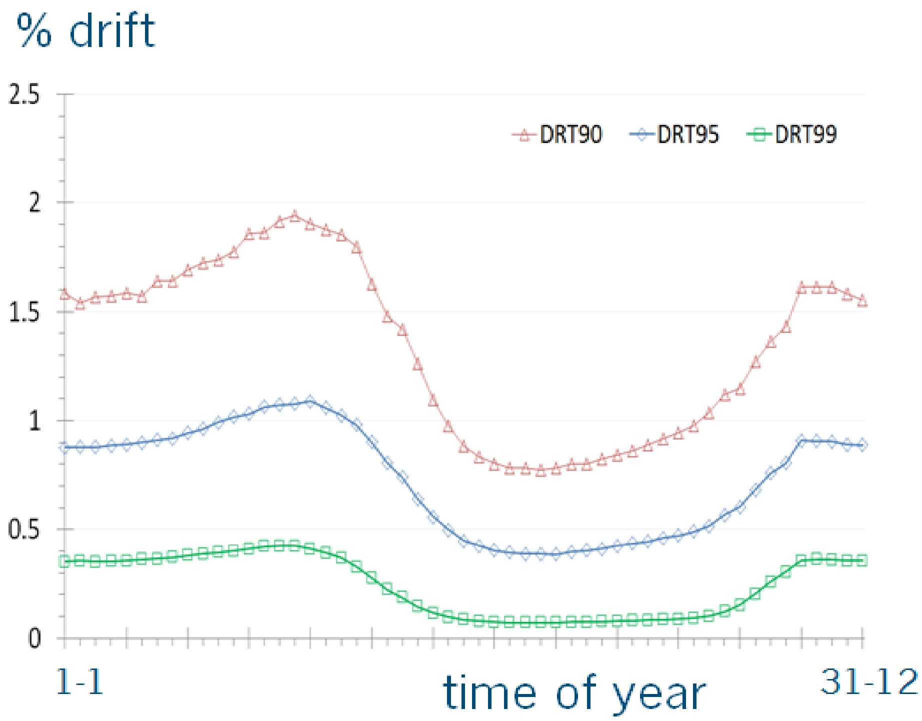

Figure 18 *Spray drift deposition as a function of application time corresponding to the 90th percentile of the STPC for single applications with zero crop-free buffer zone and DRT90, DRT95 and DRT99 as indicated; computed using xSPEXUS.*

4 Including drainage contribution in the exposure assessment

4.1 Soil type of the Andelst experimental site

Drainage can be an important exposure route when high spray drift reducing technologies are used. Therefore, an appropriate drainage scenario needs to be incorporated. Tiktak et al. (2012a) described a procedure for selecting a drainage scenario for arable soils based on data from the Andelst field site (Scorza Júnior et al., 2004). At this site sufficient data is available to parameterise and test the PEARL model including the effect on pesticide leaching of macropores. The advantage of taking a real site is that full benefit can be taken from the experimental data, so that a consistent and credible exposure scenario can be build.

As described in Section 1.3, the workgroup assumed in 2013 that Dutch fruit crops are grown on soils with lower clay contents than field crops. This hypothesis was tested by comparing the frequency distribution of the clay content of Dutch field crops with that of Dutch fruit crops (based on the GeoPEARL parameterisation). This comparison was limited to soils that are drained using drainpipes. The result in Figure 19 shows that the clay contents for the fruit crops are systematically slightly higher than those for the field crops.

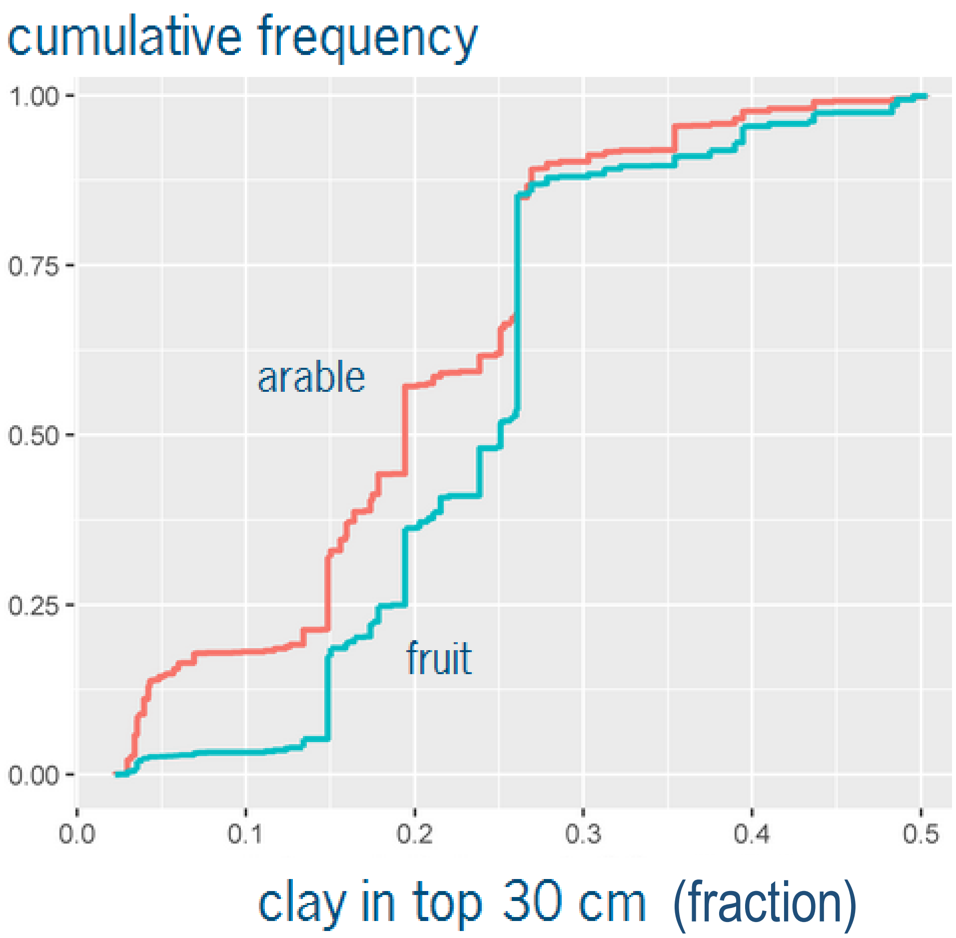

Figure 19 *Comparison of the cumulative frequency distributions of the clay content (<2μm) in the top 30 cm of (i) Dutch field crops with drainpipes and (ii) Dutch fruit crops with drainpipes.*

The Andelst soil has 28% clay in the top layer which corresponds to about the 90th percentile of the distribution in Figure 19. According to the Dutch soil map this is a light clay (Figure 20) and the USDA classification of this soil is a silty clay loam (so with a clay content too low to be classified as a clay). Comparison of the Dutch soil map of Figure 20 with the fruit-crop land use map (map not shown) indicated that in the band of this light clay between Andelst and Randwijk there are spots with more than 15% surface area fruit crops and even the research station for fruit crops in Randwijk is located in this band of light clay. So the Andelst soil is likely to be a suitable candidate for the fruit orchard scenario.

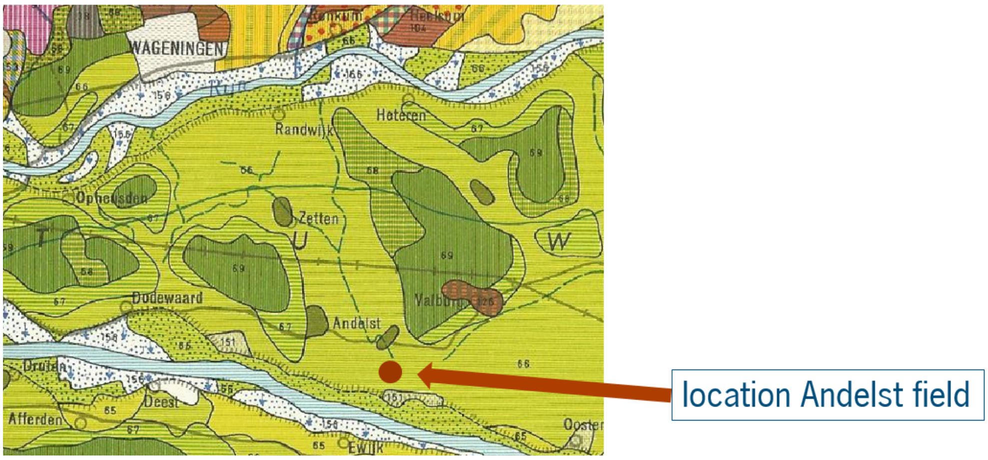

Figure 20 *The Dutch 1:25000 soil map indicating the location of the Andelst field. The soil map unit in which this location is located, is described in the legend of the map as 'somewhat sandy and light clay' with a clay content between 25 and 35%.*

4.2 Selection of the drainage scenario

As stated in section 4.1 the Andelst field site is likely to be a suitable candidate for the orchard drainage scenario. So, the problem of selecting the drainage scenario reduces to selecting the target temporal percentile to be used in the exposure assessment (conform Chapter 7 in Tiktak et al., 2012a). To account for differences between the population of arable soils and orchard soils as well as differences in crop characteristics, this procedure has been slightly modified. The sections below describe the scenario selection procedure and the results of the scenario selection.

The procedure consists of the following general steps (see also Chapter 6 in Tiktak et al. (2012a)):

1. Parameterisation of the orchard drainage scenario based on the Andelst field dataset with the PEARL model. The Andelst dataset covers only one year and applies to arable land use. So, the most important actions here are (i) to extend the dataset to a multi-year period of 15 years and (ii) to add orchard crop parameters. Crop parameters were used following FOCUS (2000).
2. Running GeoPEARL for the relevant population of orchard fields. Because GeoPEARL uses a simulation length of 20 years, this results in 20 annual peak concentrations for each GeoPEARL map unit. In GeoPEARL, substances were applied directly to the soil surface.
3. Create a cumulative frequency distribution (cfd) of all annual peak concentrations. Hereby, each peak concentration is given a weight proportional to the length of ditches adjacent to orchards. The methodology for assessing the length of the ditches is similar to Tiktak et al. (2012a). Calculate the 90th percentile from this overall cfd (red line in Figure 21).
4. Run PEARL for Andelst parameterised for an orchard crop and for 15 year of the extended meteorological data set (which is the maximum extension that could be achieved). Next, calculate a cumulative distribution function of 15 annual peak concentrations (green line in Figure 21).
5. The target temporal percentile is the temporal percentile that predicts the same concentration as the 90th percentile of the overall cfd. This percentile can be looked up by following the arrows A, B

and C in Figure 21 (similar to the procedure for spray drift as shown in Figure 13). In this example, the target percentile to be used in the exposure assessment is 20 per cent.

6. As described in Tiktak et al. (2012a), the target spatial percentile depends on the chemical substance. So, the procedure in steps 2 to 5 is repeated for 39 substances with different substance properties and a target temporal percentile is chosen that is sufficiently conservative for all 39 substances. This percentile is further used in the DRAINBOW model. The DRAINBOW model is the software instrument for use in the regulatory context.

The sections below add further detail regarding the six steps above.

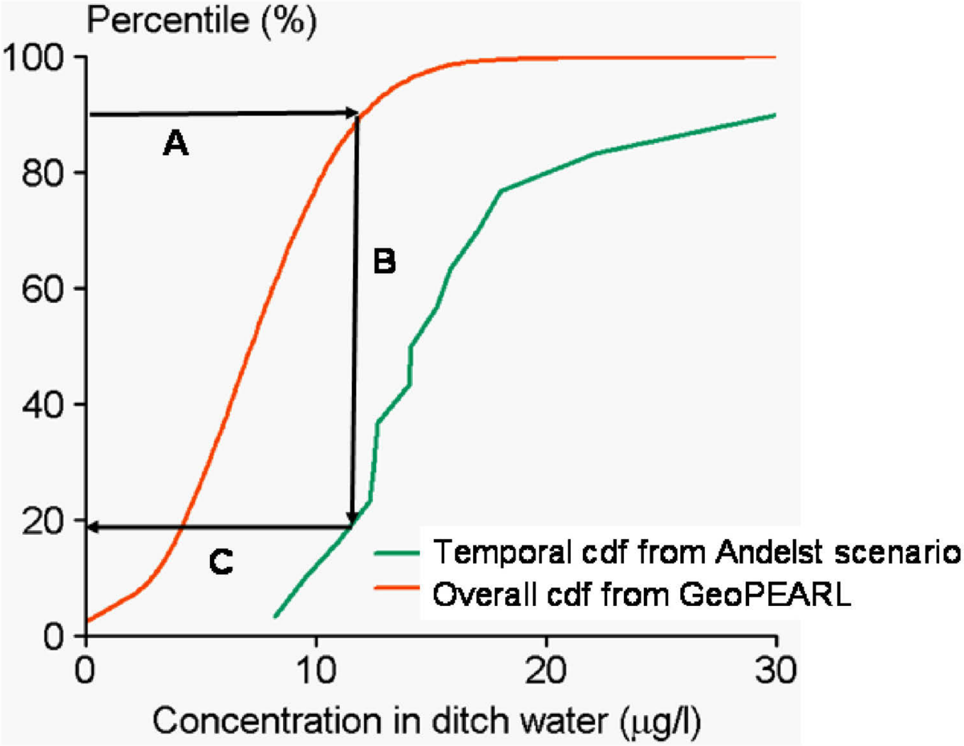

Figure 21 *Procedure to derive the target temporal percentile to be used in the exposure assessment. For the Andelst orchard scenario, the target temporal percentile predicts the same concentration as the 90th percentile of the overall cumulative distribution function for all Dutch orchards of GeoPEARL (red line).*

1. Parameterisation of the orchard drainage scenario (for the scenario selection)

The drainage scenario is based on data from the Andelst field site. Two actions were carried out to adapt the Andelst dataset to the needs of an orchard drainage scenario, i.e. (i) the scenario was extended to a multi-year period, and (ii) instead of an arable crop, an orchard crop was added.

The Andelst dataset covers a period of one year, so this needs to be extended to a multi-year period. We used data from the nearby weather station Herwijnen for this purpose. Notice that for the arable crop, weather data from De Bilt was used, but this weather station is farther away. The lower boundary condition of the (soil-hydrology) SWAP model is taken from borehole B39H0311 in the DINO database (www.dinoloket.nl). This borehole is situated at approximately 1 km from the Andelst field site and contains data for the period 1991 – 2005 (i.e. 15 years). Hydraulic heads were adjusted to account for the difference in altitude between the two sites (see Tiktak et al. (2012a), page 51 for details).

For the orchard drainage scenario, apples from the FOCUS Groundwater Hamburg scenario were selected. No tillage was assumed and no irrigation (see also Table 2 for summary of the characteristic of the orchard drainage scenario and the changes that were made as compared to the arable crop scenario). No distinction was made between the rows and the area between the rows. The pesticides were applied annually to the soil surface at April 7. All substance properties except for the half-life and the sorption coefficient were set equal to that of FOCUS substance D. A total of 39 substances was included in the simulation (see also Tiktak et al. 2012a, Table 3). The substance was applied directly to the soil surface, hence 100 percent of the applied dose was considered to be deposited on the soil surface.

Table 2 *Overview of differences between the Andelst field dataset, the Andelst scenario for arable crops and the Andelst scenario for orchards.*

Property	Andelst field dataset*	Andelst arable crop scenario	Andelst orchard scenario
Time period	April 1998 until April 1999	1991-2005 (first five years copied to obtain a warm-up period).	1991-2005 (first five years copied to obtain a warm-up period).
Weather data	Rainfall measured on-site, other parameters from weather station Wageningen at 10 km from site.	Weather station De Bilt at 40 km from site. Rainfall assigned to first hours of day.	Weather station Herwijnen. Rainfall assigned to first hours of day.
Hydrological lower boundary condition	Measured on-site.	Fortnightly measurements from a groundwater bore hole at 1 km from site.	Fortnightly measurements from a groundwater bore hole at 1 km from site.
Plough date and depth	December 8, 26 cm	October 15 each year, 20 cm	No ploughing
Root density distribution	As observed at Andelst site	Conform FOCUS (2000), i.e. uniform.	Conform FOCUS (2000), i.e. uniform.
Pesticide applications	One pesticide application.	Annual applications of pesticide.	Annual applications of pesticide.

*) original calibration, see Section 5.3 in Tiktak et al., 2012a) for details.

The TOXSWA metamodel (Tiktak et al., 2012b) was used to calculate the concentration in the receiving water course.

2. Running the GeoPEARL model for the relevant population of fields
In view of the available budget, we did not repeat the GeoPEARL simulations but used the GeoPEARL outputs that were created for selecting the arable drainage scenario (Tiktak et al. (2012a), page 43). This was possible, because these runs were carried out for all unique combinations of land-use, soil type and climatic zoned available in GeoPEARL.

The GeoPEARL simulations for the arable drainage scenario were based on the standard crops potatoes, winter wheat, maize and grass whereas the PEARL simulations for Andelst were made for a fruit crop. In principle, the GeoPEARL calculations should also have been based on a fruit crop. However, this was not feasible (see Tiktak et al., 2012b, p. 83 for the background). Moreover, the crop type has probably only a small effect on the cumulative drain flow (see Tiktak et al., 2012b, p. 56) and thus also probably only a small effect on substance leaching.

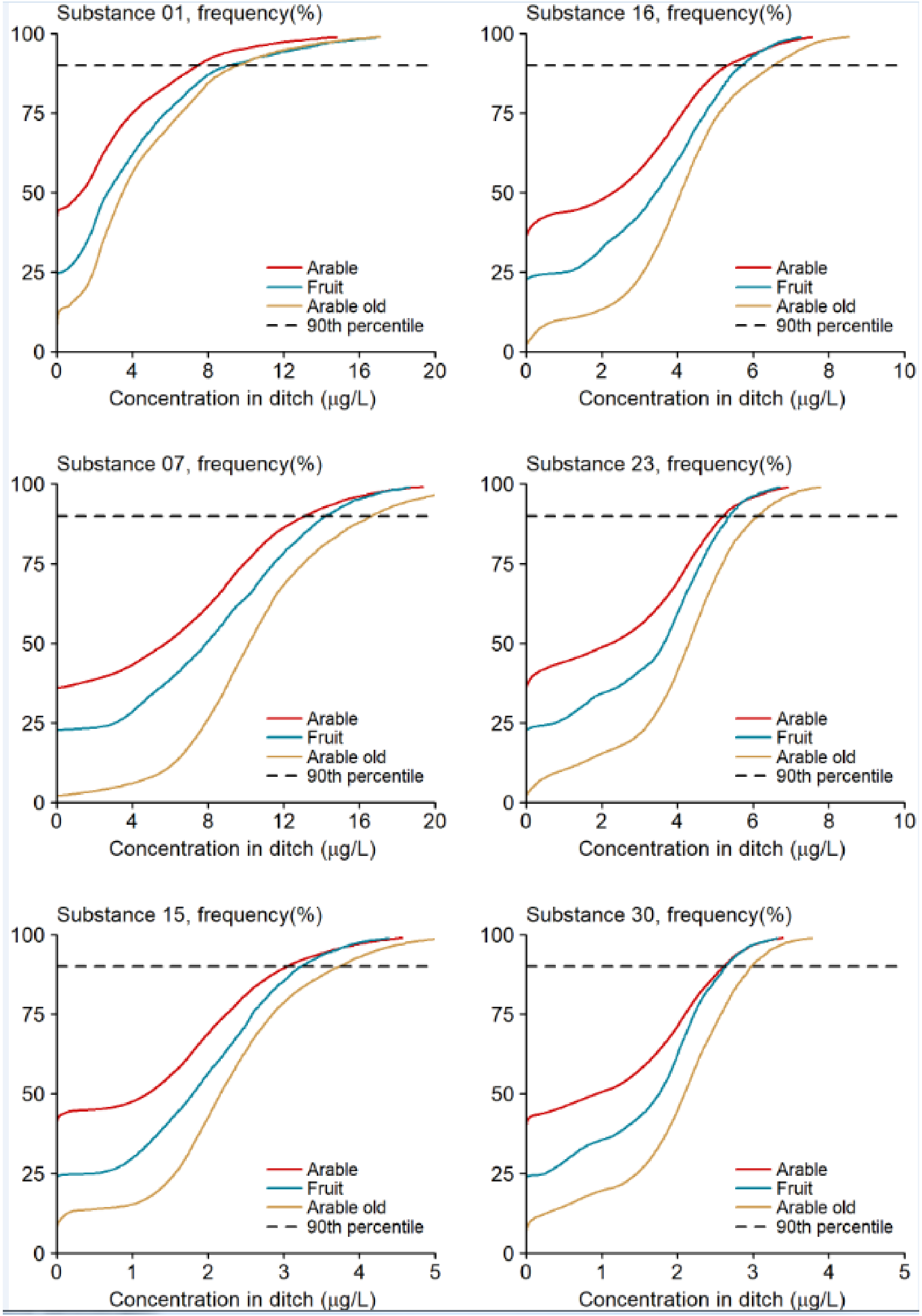

Figure 22 *Comparison of the overall cfd for the arable ditches and for the orchard ditches for 6 arbitrary selected substances out of the 39 simulated substances. The red line gives the overall cfd for arable crops and the blue line for fruit crops. The yellow line refers to the (old) situation in which also the water bodies were included which could fall dry in summer and also only drained ditches were selected.*

3. Creating a cumulative frequency distribution of all peak concentrations

Because the GeoPEARL runs were already available, the task of the current working group was reduced to creating an appropriate frequency distribution from the existing GeoPEARL runs. As described in Tiktak et al. (2012a), for the construction of the overall frequency distribution, all annual maximum concentrations were used, so the number of datapoints was 6,405 (the number of GeoPEARL map units) x 20 (the number of years in GeoPEARL) x 2 (the number of ditch types within each GeoPEARL map unit) = 256,200. There are two ditch types within a map unit, because a distinction was made between secondary and tertiary ditches. Weighting factors were assigned to each data point, based on the lineic length of the water courses (Figure 19 in Tiktak et al. 2012a). In Tiktak et al. (2012a), temporarily dry falling ditches were included in the dataset. In the selection of the orchard drainage scenario, these ditches were excluded (see Section 1.2). The effect of this new assumption is shown in Figure 22 for arable crops (difference between the red and the yellow lines). The weighting factor is further affected by the fraction of the corresponding land-use within each map unit. So for the selection of the orchard drainage scenarios, the fraction of arable soil as replaced by the fraction of orchard soils within each map unit. The final result is indicated by the blue line in Figure 22. Figure 22 shows that the spatial 90th percentiles for the orchard ditches are generally higher than the 90th percentile for the arable ditches (compare the blue and the red lines). The frequency distributions were originally based on drained fields only. A correction was made to include undrained fields. The red line shows around 22% max concentrations that are zero. These correspond to the undrained orchards (no emission via drains).

4. Calculating the temporal frequency distribution for the selected orchard scenario
The temporal frequency distributions for the 39 substances are obtained from the (Andelst) model runs described in step 1. However, a slight modification of these runs is needed before a fair comparison can be made with the GeoPEARL runs. The reason is that Tiktak et al. (2012a) identified that the organic matter content for the Andelst scenario was lower than the organic matter contents in the corresponding GeoPEARL plot. Further inspection of the GeoPEARL dataset revealed that organic matter contents were dominated by grassland soils. It is well known that the organic matter content of grassland soils is higher than the organic matter content of arable soils. To account for these differences, we have multiplied the organic matter content of the Andelst scenario by a factor of 1.56 (see Tiktak et al. 2021a for a justification). Notice that this scaling has only been done for the purpose of the calculation of the temporal percentiles. In the final simulations, the organic matter content was kept at its original value of 2.1 per cent, which is, as indicated, typical of an arable soil (see further Tiktak et al. 2012a, page 84).

5. The target temporal percentile
The target temporal percentile is the temporal percentile at the orchard scenario that predicts the same concentration as the 90th percentile of the overall cfd. This percentile can be looked up by following the arrows in Figure 21. Results for all 39 substances are shown in Table 3. As discussed in Tiktak et al. (2012a), the target percentile decreases with increasing Kom and with increasing DegT50.

Table 3 *Target temporal percentile for the 39 example substances. The target temporal percentile is the temporal percentile at the scaled orchard scenario that predicts the same concentration as the 90th percentile of the overall frequency distribution.*

	Kom (L/kg)						
DegT50 (d)	**10**	**20**	**30**	**60**	**120**	**240**	**480**
10	63	63	57	50	43	30	23
20	57	50	50	50	43	30	17
30	50	50	57	50	50	30	17
60	-	23	23	37	30	30	17
120	-	-	30	17	23	30	17
240	-	-	-	17	17	17	17
480	-	-	-	-	17	17	23

6. Temporal percentile to be used in DRAINBOW
As shown in Table 3, the target temporal percentile is substance dependent. One possible solution would be to include all these temporal percentiles in the software tool DRAINBOW and let the software tool automatically select the temporal percentile. There are, however, uncertainties in the selection of the temporal percentile. One uncertainty arises from the use of the simplified boundary condition in GeoPEARL: it consists of a long-term average soil water flux on which a sine function is imposed (Kroon et al., 2001). Additional analyses showed that due to the use of this approach, the differences between the years are underestimated. In view of this uncertainty, the working group considered it more appropriate to use only one temporal percentile in DRAINBOW. This temporal percentile should

be sufficiently conservative for all substances. Figure 23 shows the ratio between the predicted concentration for a certain temporal percentile at the orchard scenario and the overall 90th percentile predicted by GeoPEARL for the 39 substances. This figure shows that the 63rd temporal percentile is sufficiently conservative for all substances (i.e. the ratio > 1). This means that the PEC associated with the temporal percentile overestimates the countrywide PEC90 by that same ratio. The working group judged the overestimation of the exposure concentration for most substances reasonable because of the uncertainty associated with (i) the scaling of organic matter content between the orchard scenario and the GeoPEARL scenario's, (ii) the effect of the lower boundary condition, and (iii) the fact that uncertainty of substance properties resulting in a possible shift of the overall drainage concentration to higher values has not been taken into account. So the final recommended percentile to be used in DRAINBOW is the 63th percentile.

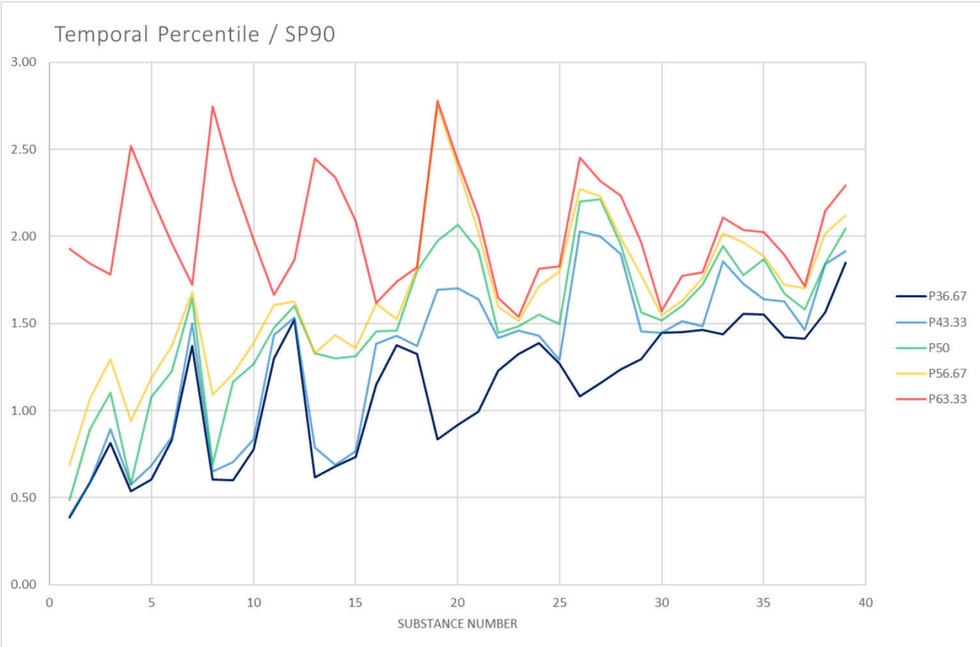

Figure 23 *Ratio of the predicted concentration for a certain temporal percentile at the orchard scenario and the overall 90th percentile concentration predicted by GeoPEARL, for fruit orchards and for the 39 substances considered.*

4.3 Determination of T90 when both spray drift and drainage occur

For both entry routes, spray drift deposition and drainpipe emission, a methodology to derive PEC90 was developed, while using the same selected spatial unit. However, the drift deposition scenario derivation did not explicitly consider the contribution of the drainage and vice versa, i.e. for deriving the temporal percentiles for drift deposition only drift was considered as entry route and for temporal percentiles of drainage only the drainage was considered. The separate drift and drainage scenarios have different temporal percentiles. The reason for this approach is historical, i.e. initially it was assumed that the contribution of drainage was negligible as compared to drift deposition. However, for drift reducing techniques with a reduction percentage of 99% it was shown that the contribution of drainage was not negligible for mobile substances (Boesten et al. 2018).

A protocol was developed to select a temporal percentile when both drift and drainage occur in one simulation which should result in a protective PEC90, but not too protective.

Protocol

The proposed protocol offers a simple but reasonable solution. Basically, if spray drift is the major entry route in the simulation, the temporal percentile for drift is used. If drainage is the major entry route, the temporal percentile for drainage is to be used. If both contributions may play a role, the maximum of both temporal percentiles is taken (conservative approach)[9].

As before, the focus is on the (15) annual peak values of the PEC (PEC_{max}). The contribution of the spray drift at each of the 15 dates of the PEC_{max} is represented by the expected concentration due to drift only (while neglecting other processes); this is called PEC_{drift}. Similarly, the contribution of the drain emission is represented by the expected concentration due to drain emission only, i.e. PEC_{drain}. As drainage events may occur during several subsequent hours, merely looking at the hour of spray application may not be representative for the drain contribution to PEC_{max}, i.e. PEC_{drain}. Therefore, the concentration in the drainage water averaged over the entire 24 hours of the day of application was considered to be a better representative of the PEC_{max} due to drainage emission. See Annex 2 for a more detailed justification of this approach.

The protocol has the following subsequent steps:

1. Carry out the computations for the multi-year simulation. Let's assume that the number of simulated years is N;
2. The xSPEXUS spray drift model returns the temporal percentile to be used (T90) based on the drift scenario;
3. Determine the N annual maximum PEC levels over the multiyear simulation and the corresponding dates at which these maxima occur (d_1);
4. Determine the pesticide concentration PEC_{drift} (mg m^{-3}) due to drift deposits in the evaluation ditch, on the dates d_1;
5. Determine the pesticide concentration PEC_{drain} (mg m^{-3}) due to drain deposits in the evaluation ditch, on the dates d_1;
6. Compare PEC_{drift} and PEC_{drain} for each d_1; if $PEC_{drift} > 2^* PEC_{drain}$ then drift is considered as dominant for this year, if $2^*PEC_{drift} < PEC_{drain}$ then drain emission is considered as dominant for this year, for all other situations the dominance is not distinguishable; this results in a number of drift dominated years (N_{drift}), a number of drain emission dominated years (N_{drain}), and a number of years of which the PEC_{max} is due to both emission routes (N_{both}), where $N_{drift} + N_{drain} + N_{both} = N$;
7. If $N_{drift} \geq 2/3$ N then select the T90 that belongs to the drift scenario; if $N_{drain} \geq 2/3$ N then select the T90 that belongs to the drain pipe scenario, i.e. 63%; in all other situations select the maximum T90 of both.

For one application per year, a correction on the number of drainage dominant years is required to assure that drainage really is dominant in that scenario. This is explained as follows. In case of only one spray application per year, the chance that the drift is zero is around 37 percent for the selected local situation (see Section 3.4.3). Since spray drift deposits are sampled from the ideal *cfd* (Section 3.6), this implies that in at least 5 years out of 15 simulation years the spray drift deposits will be zero. This means that in these 5 years drainage is dominant, no matter how small drainage might be. So the number of years where drainage is dominant has 5 years 'for free'. If in half of the remaining 10 years drainage would be dominant as well (which is quite probable if drift and drainage happen to be almost equally important), then a total of 10 years with drainage as the major route is easily obtained (which is 2/3 of 15 years). Step 7 then states that drainage is the dominant route for the 15 year scenario, even though the two routes might be almost equal in strength. To have slightly more certainty in the choice made, an additional year of drainage dominance is required. Therefore, step 8 is added to increase the boundary level for N_{drain} for simulations with one annual spray application:

8. In case of one spray application per year, the boundary level for N_{drain} is increased by one: so if $N_{drain} \geq 2/3N + 1$ then select the T90 that belongs to the drain pipe scenario, i.e. 63%; for more than one application per year, step 7 remains valid.

[9] A simpler alternative would be to first simulate the input from drift deposition and find the PEC_{drift}, secondly the simulation is done with drain emission only to find the PEC_{drain} and then the simulation is run with both routes and the year is selected that belongs to the highest of these two PEC values. It was decided to develop a method with one simulation only in view of saving simulation time.

Note that only for N_{drain} the level is increased in step 8. For N_{drift} there is no need to raise it, since with one application per year, 10 out of 15 years (2/3 N) of dominant drift is the most we can get, in which case drift certainly is the dominant route of this scenario. For more than one spray applications per year the number of years with zero drift deposits is very low and the 2/3 N boundary can be used confidently. It can be shown that for other numbers of years than 15 years, the boundary levels 2/3 N and 2/3N+1 (the latter as in step 8) are confident as well.

The sensitivity of the drift scenario to the selection of the temporal percentile is assessed in Annex 3. The results showed that for some of the DRT classes the impact of using a different T90 than needed to achieve an overall protection level of 90 percent could be large.

4.4 Parameterisation of drainage emission scenario

The parameterisation of the selected drainage emission scenario was further refined based on a detailed assessment of current orchard management practices in the Netherlands. The refinement considered mostly the orchard configuration, crop parameters and management practices, aspects for which that parameterisation was based on the FOCUS Apple scenario. In this section pesticide fate specific aspects in the soil compartment are discussed. We refer to Ter Horst et al (2020) for further detail. Also the parameterisation of the soil-hydrological model (SWAP) underlying the PEARL model is described in Ter Horst et al. (2020). The parameterisation of the evaluation ditch is discussed in Chapter 5.

Dutch apple orchards consist of apple trees that are commonly grown in rows at a distance of 3 m with 1 m distance between the trees in a row. This results in 3333 trees per ha. The ground strip below the trees is kept bare and has a width of about 1 m. Grass is grown between the last row and the edge of the field (Figure 9) and on the path between the rows and has a width of 2 m (Figure 24).

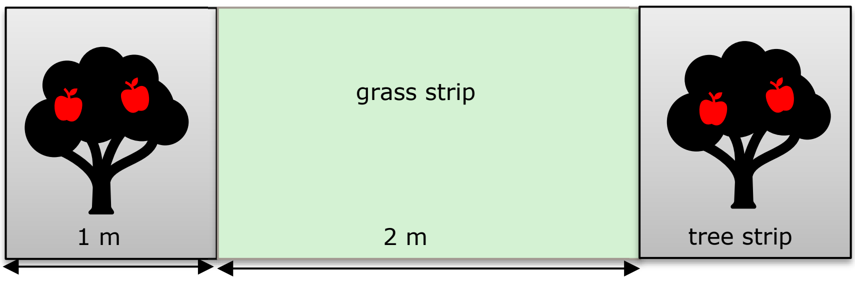

Figure 24 *Geometry of a typical Dutch apple orchard.*

From a hydrological point of view apple orchards can be regarded as a two-dimensional system consisting of alternating 1-m strip of trees and a 2-m strip of grass. Each of these strips contribute to drainpipes that discharge to the edge-of-field ditch. Given that the soil-hydrological model (SWAP model) is a one-dimensional model, Ter Horst et al. (2020) concluded that the most realistic approach would be to simulate drainage discharge fluxes for the tree strip and the grass strip as separate systems and to merge the water and pesticide mass fluxes in a follow up step based on area weighting[10] (on a 1-h basis). Below the parameterisation of the pesticide fate model (PEARL) is discussed, that uses the hydrological output from the hydrological model. For further detail on the hydrological parameterisation we refer to Ter Horst et al. (2020).

Simulating the tree strips and the grass strips separately in the pesticide fate model PEARL, means that the pesticide mass deposits on soil and crops need to be quantified for tree strip and grass strip separately. Two aspects play a role: first, when applying pesticide to the trees, the fractions depositing onto the ground at the tree strip and at the grass strip are different (Van de Zande et al.,

[10] In practice this is done by combining the PEARL output file *.e2t of the tree strip and grass strip in to one *.e2t.

2019), second, the fraction of the applied spray intercepted by the crop (i.e. trees on the tree strip and grass on the grass strip) is different on these two strips. For conventional spray techniques, the average deposition percentage on the bare soil under the trees is about 60% of the applied dose (dose defined as mass per area of the field) and the average deposition percentage for the grass strip was about 40% of the applied dose (Boesten et al., 2018). These values are estimates based on a best guess. Note, that it is a coincidence that adding these percentages results in 100%.

Assuming an area ratio of 1/3 for the tree strips and 2/3 for the grass strips in a Dutch orchard (see Figure 24), this results in a deposition on the bare soil of the tree strips of 0.33 × 60% = 20% of the total applied mass and on the grass strips of 0.67 × 40% = 27% of the total applied mass. This means that on average 100% - 20% - 27% = 53% of the applied mass is deposited on the trees. Thus, 73% of the applied mass (20% deposition on the bare soil + 53% deposition on the trees) is applied towards the tree strips including the trees at those strips[11].

Based on the information above, two scenarios were computed: first, assuming the whole area is tree strip and second, assuming the whole area is grass strip. Afterwards, the two results were combined while weighting according to the actual areal ratios for tree strips and grass strips.

To get the total percentage of the dose in line with the percentages above, the dose derived above (73% of the applied mass on the tree strip and 27% on the grass strip) should be multiplied by the inverse of their respective areal ratios. This means that for an imaginary orchard of only grass strips the dose as mentioned on the pesticide label and to be applied in the orchard needs to be multiplied by a factor of 0.4 (i.e. 0.27 * 3/2 = 40% of the intended dose) and for an imaginary orchard of only tree-strips the dose needs to be multiplied by a factor 2.2 (i.e. 0.73 * 3/1 = 220% of the intended dose). These 'dose adjustment factors' of 0.4 for the grass strip and 2.2 for the tree strip are applied irrespective of the spray application technique[12].

Note that the adjustment factors are applied irrespective of the application technique/ DRT class used. These adjustment factors are based on limited experimental data and expert knowledge on fraction of the applied dose depositing on the trees, the bare soil below the trees and the grass strip in between the trees. There is no additional data available that supports further refinement in the adjustment factors.

The fraction of pesticide intercepted by the trees is 53/73 = 0.726. It is assumed that this value can be used throughout the growing season and that the interception is independent of the spray application used[13]. By using the approach above, the crop interception values provided by Van de Zande et al. (2019) for orchard crops are being overruled. For the grass strip simulations, the crop interception for grass should be taken in account. We assume 90% interception for the grass strip which is in line with EFSA (2014) that mentions the same interception for permanent grass.

A fraction of the deposited substance on the plants may be washed off to the soil by rain. The rate of wash-off is considered to be dependent on the rainfall intensity and a wash off coefficient. We refer to Van den Berg et al. (2016). For the wash off factor we propose to use the conservative value of 100 m^{-1} (0.01 mm^{-1}) which is based on EFSA (2017).

A check was performed whether the followed approach results in correct mass balances in the PEARL model, which is described in Annex 4.

[11] In van de Zande et al. (2019), Table 20, interception values are mentioned between 50-65% for development stages BBCH 10-69 and ca. 65% for BBCH 70-95. EFSA (2020) uses 65 percent interception. This implies that the value of 53% derived here is conservative. Also, the values are lower than those used in the repaired FOCUS surface water scenarios (EFSA, 2020). EFSA (2020) gives crop interception for pome/stone fruits between 60-65%, which implies that 40-35% is deposited directly to the soil surface. Note that EFSA (2020) does not consider (explicitly) the grass strip.

[12] Later on the concentrations in the drain pipes are added while weighing the grass strip as 2/3 and the tree strip as 1/3.

[13] This implies that it also applies for bare trees.

5 Parameterisation of TOXSWA for the selected scenario

5.1 Dimensions of the ditch

One scenario was selected with an edge-of-field ditch of the hydrotype, Betuwe stroomruggronden, secondary ditch. The corresponding mean ditch geometry was taken from Massop et al. (2006), as listed in Table 4 and as depicted in Figure 25.

Table 4 *Dimensions of the selected ditch for the upwards and sideways directed spraying scenario.*

Symbol	Description	Ditch properties
	Hydrotype	Betuwe stroomruggronden
	Ditch type	secondary ditch
t	Width top ditch (m)	3.90
b	Width bottom ditch (m)	1.74
w	Width water (m)	2.34
h	Water depth (m)	0.30
A	Lineic volume (m^3 m^{-1})	0.612
s_1	Slope (horizontal:vertical)	1

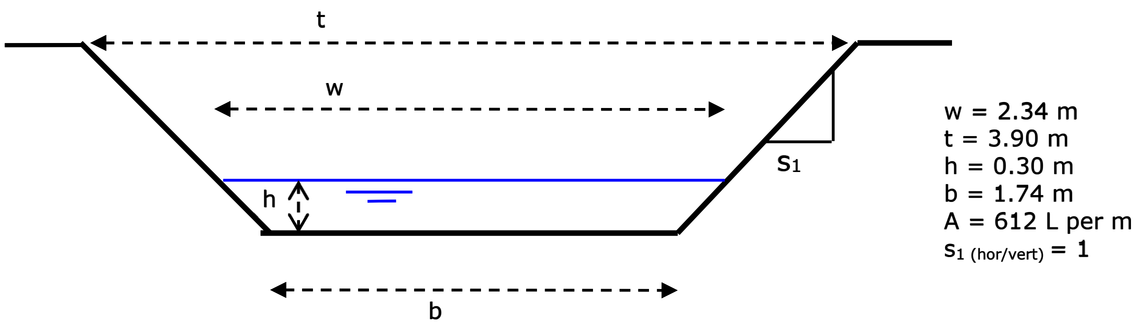

Figure 25 *Dimensions of the ditch for the selected scenario, where w is the width of the water surface, h is the water depth, b is the width of the bottom of the ditch, t is the width of the top of the ditch, s1 is the side slope (horizontal/vertical), and A is the lineic volume of the water in the ditch.*

In line with preceding exposure assessment methodologies, the length of the evaluation ditch is 100 m, i.e. the calculated Predicted Environmental Concentration (PEC) is the concentration averaged over 100 m of ditch (e.g. Tiktak et al., 2012a).

5.2 Position of the ditch in the landscape

Based on geographical data, the distance between the ditches was estimated at 140 m and the length of a ditch parallel to the tree rows of an orchard was estimated at 100 m (rounded numbers; see Wipfler et al., 2018, for details). The total length of the simulated ditch was 300 m of which the middle 100 m was assumed to be treated with pesticide (Figure 26). It was assumed that the water that flew into the ditch from either side contained no pesticide.

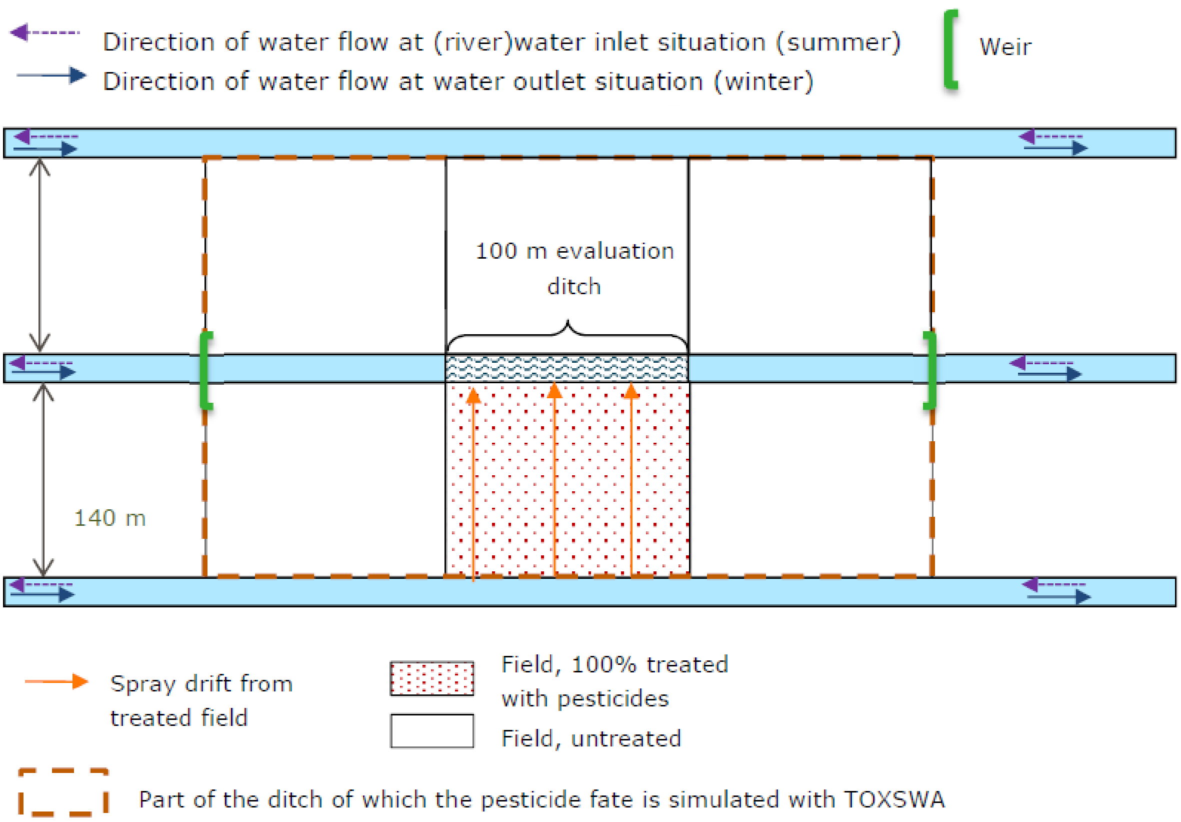

Figure 26 *Schematic representation of the position of the evaluation ditch in the landscape.*

5.3 Parameterisation of the water flow rates

As described above, the scenario selection procedure included the water depth of the ditch. This is considered to be the most important hydrological property of the ditch for spray drift because the maximum concentration occurring after a spray drift event is approximately inversely proportional to this water depth. However, also the water flow rates in the ditch may have a considerable effect on the annual maximum concentration in case of repeated applications. Therefore considerable attention was payed to the parameterisation of this flow rate. Wipfler et al. (2018) describe this parameterisation in detail, so here only a brief summary is given.

The water flow rate was based on simulations with the Moria 2.2 model (Borren and Hoogewoud, 2014). This is a groundwater model specially developed and calibrated for the Rivierenland area. The model has a resolution of 250 x 250 m and solves per grid cell the daily water balance based on exchange fluxes with adjacent grid cells, incoming precipitation and outgoing evapotranspiration and also the exchange with surface water bodies such as ditches or ponds. The model has been calibrated for the period 01-04-2002 to 01-04-2011; over this period daily groundwater-surface water exchange fluxes are available for five areas within Rivierenland, i.e. the Betuwe-Linge area, the Bommelerwaard, the Lek and Linge area, the Maurikse Wetering area and the Tielerwaard.

To obtain flow rates that are as realistic as possible for ditches at the edge of fruit orchards, only grid cells were selected that were located in a unit ('peilvak') that has (1) >15% fruit crops, (2) >50% of secondary water courses (width < 3 m), and (3) 'Betuwe stroomruggronden' as the dominant hydrotype. At the end 110 grids remained. From the daily elements of the water balance, a time series of daily water flow rates in the ditch were derived for each unit for the period 2002-2011 using a simple model. This time series was used to feed a direct sampling technique which generated a time series of daily flow rates for the 26-year period needed for the TOXSWA simulations[14]. A typical

[14] Note that in the developed scenario only 20 year were used, which covers the 5 years of warming up.

characteristic of the derived flow velocities is that the flow direction alternates seasonally due to changes in precipitation and water demand.

5.4 Drainage contribution

For the drainage contribution the PEARL model was parameterised. As explained in Chapter 4 the drainage scenario is based on data from the Andelst field site. Specific orchard characteristics were then added, while differentiating between the tree strip, with the bare soil under the trees and the grass strip. Also a differentiation was made between types of irrigation, i.e. drip irrigation for the trees and the supply of water by sprinkler irrigation in case of night frost during the blooming period. We refer to Ter Horst et al. (2020) for further detail of the parameterisation.

5.5 Calibration of the hydrological sub-model of TOXSWA

The SWQN model (Smit et al., 2009) was used to describe water flow rates and water depths in the ditch as a function of time (Ter Horst et al. 2020, for details), using the flow rates as boundary conditions and the drainage fluxes from the previous sections.

The model described the water flow in the 300 m long ditch segment between the two weirs in Figure 26 (these weirs maintain the water depth at the required level, one for each direction of flow). The time course of the water depths was calibrated based on the requirement that both the winter and summer water depth should be 30 cm. It was assumed that the 83rd percentile of the winter water depths should be 30 cm and that the 50th percentile of the summer and winter water depths are equal[15]. Resulting water depths after the calibration are shown in Figure 27. The minimum water depth is about 27 cm and that occasionally water depths up to about 43 cm occur. The 50th percentile of the summer and winter water depths was 28 cm.

As described before (section 3.4.2), it was assumed in the scenario development procedure that the residence time of the water in the ditch was short such that accumulation of pesticide due to repeated applications is unlikely to occur. This is illustrated by the frequency distribution of instantaneous residence times for the full calendar years shown in Figure 28. Figure 28 gives a median residence time of about 0.5 d for the full calendar year. Graphs of rainfall and drainage events as a function of time are provided in Annex 5.

[15] The winter water depth was assumed to 'exceed the mean highest water level 30 days a year'. This excess belongs to the winter situation only (six months). Hence, the percentile corresponding to the water depth of 30 cm will be: 100-(100 * 30/180) = 83.33th percentile (Wipfler et al., 2018).

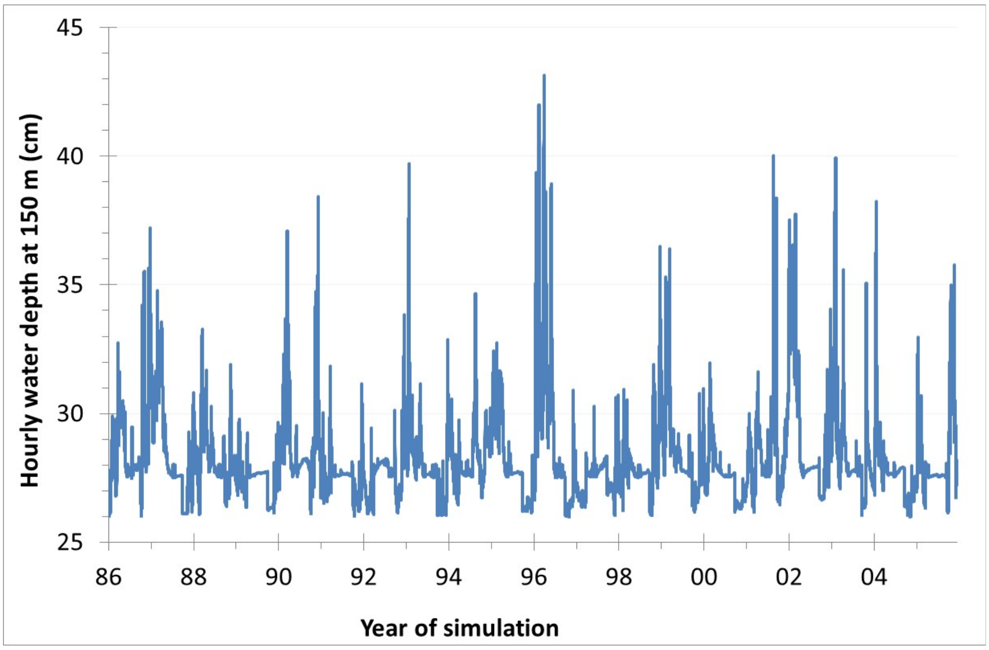

Figure 27 *Simulated water depth as a function of time for the 20-year period from 1986-2006 (5 years warm-up period and 15 evaluation years). Note that the vertical axis starts at 25 cm.*

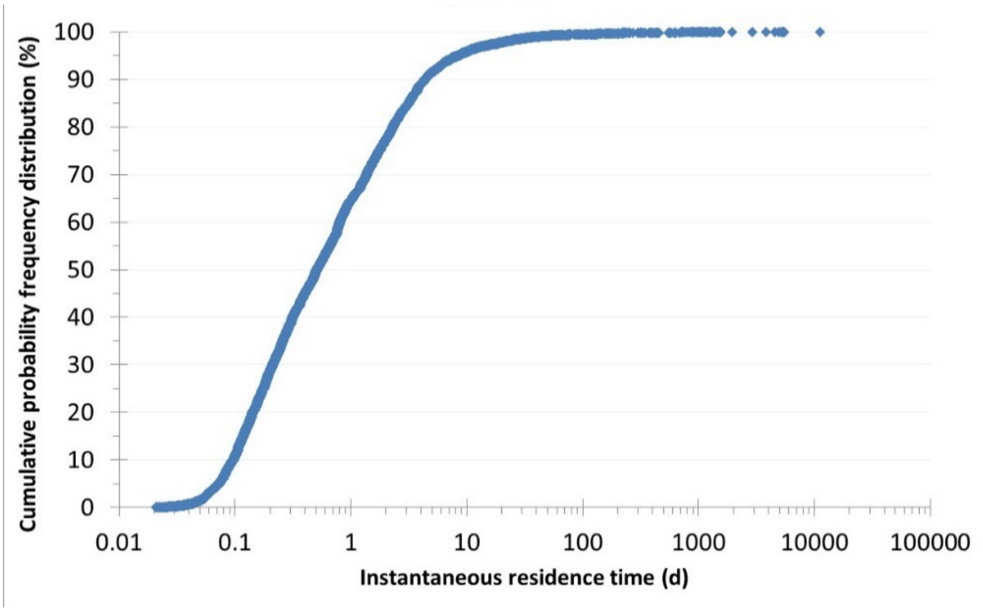

Figure 28 *Cumulative frequency distribution of the residence time in the 100-m evaluation ditch for the 15 simulation years (1991-2005) used for evaluation.*

5.6 Estimation of other TOXSWA input parameters

Water temperature

The temperature in the water is simulated and may vary per hour. The approach, which is described in Beltman et al. (2018) includes the simulation of inflow of energy via drainage water. Hourly data from the KNMI Meteostation Herwijnen were used as input for the simulations. These temperatures are calculated by the SWAP-PEARL model and provided to TOXSWA.

Sediment properties

TOXSWA requires as input the properties of the sediment. From the available Dutch measurements of sediment properties, measurements at four locations were selected because of their relevance for

Dutch fruit crops. The two locations with the highest and the lowest organic matter content were selected and these were used to assess the sensitivity of the exposure endpoint to the sediment properties (see Wipfler et al., 2018, and Adriaanse et al., 2015, for details). Results in Table 5 show that the lowest organic matter content (at Willemstad) is somewhat higher than the 9% used in the FOCUS surface water scenarios.

In Chapter 6 example calculations with the developed scenario are executed. Also, the impact is assessed of the sediment properties of the water course. Calculations with a strongly adsorbing substance revealed that the PEC90 is sensitive to the sediment characteristics. It was decided to select the properties that give the highest PEC90 in the water layer for the scenario parameterisation, which are the properties of Willemstad.

Table 5 *Properties of the sediment from the two selected locations.*

Layer	Organic matter content (%)		Dry bulk density (kg/L)	
	Willemstad	Benschop	Willemstad	Benschop
0-1 cm	12	22	0.32	0.12
1-10 cm	10	24	0.49	0.20

5.7 Discretisation of the sediment layer

We follow vertical discretisation as proposed by Beltman et al. (2018) (see also Annex 7). To obtain convergence of the numerical solution of the mass balance equation of the sediment, it is advised to use thinner sediment segments for compounds with a higher sorption coefficient. We propose to follow the FOCUS surface water approach that recommends a finer discretisation for a Koc value larger than 30 000 L/kg. The software DRAINBOW will provide the option for the user to move towards a finer discretisation. Note however that for substances with a low Koc value the finer discretisation may in some cases lead to numerical instability. We refer to Annex 7 for the concrete discretisation that has been adopted, for the standard discretisation of the sediment and the refined discretisation.

6 Example calculations

6.1 Objectives of the example calculations

Calculations with the parameterised scenario are done for three compounds which are commonly used in Dutch fruit cultivation and their corresponding application patterns. First of all these calculations are performed to demonstrate the calculation procedure and to establish the driver of the annual PEC_{max}, i.e. spray drift or drain flow. Secondly, these calculations are performed to obtain more insight in the combined effect of hydrology of the scenario ditch, the compound properties, the number of applications and the type of entry route on the annual PEC_{max}.

The example calculations with one of the three compounds, a strongly adsorbing pyrethroid, are used to analyse the sensitivity of the PEC in the water to the sediment properties. Ter Horst et al. (2020) describes four locations in the Netherlands for which detailed sediment properties are available. From these four locations two were selected; the properties based on the locations Willemstad and Benschop were considered suitable and the selection of one of the two is done based on the outcomes of the example runs with these two types of sediment characterisations (Section 6.6).

While the drift deposition scenario shows a gradual course of depositions as a function of the application date (see Figure 18), the sensitivity of the drain emission scenario to the application date is yet unknown. In Section 6.7 the sensitivity to the application date is assessed for situations in which drain emission is considered to be dominant.

6.2 Scenario calculation procedure

For the calculation of the Predicted Environmental Concentration, being the 90th percentile of the overall STPC, TOXSWA receives mass input from both drainage and drift deposition. The input from drainage is provided by the PEARL model, which calculates the fate in the soil-vegetation compartment based on substance properties and dose. Spray drift deposits are calculated by the local spray drift deposition model xSPEXUS.

Next, TOXSWA calculates the concentration in the water phase over 15 year with a so-called warming-up period of 5 years. The percentile year for the risk assessment is selected according to the procedure described in section 4.3.

For the example calculations the sediment properties of the location Benschop were used (see Annex 7). However, calculations with both sediments (Willemstad: organic matter fraction of the top 1 cm of 0.124 and Benschop: organic matter fraction of the top 1 cm of 0.22, see Annex 7) were done for one of the three compounds. For this substance (i.e. a pyrethroid with a high sorption coefficient) the sediment discretisation follows the FOCUS Surface Water high KOC sediment parameterisation (see Beltman et al., 2018). The organic matter fraction of the suspended solids in the water layer was set to the organic matter fraction of the top 1 cm of the sediment.

The concentration of suspended solids in the water layer was set at 11 g m^{-3} (Tiktak et al., 2012a) and the mass fraction of organic matter was set to the mass fraction of organic matter of the top 1 cm of the sediment (0.22 for the location Benschop).

Simulations with TOXSWA were done over a period of 20 years (15 years: 1991-2005 + 5 years warming-up: 1986 - 1990). The simulation period is confined by the use of the extended Andelst data set. The original Andelst dataset could be extended to only 15 years (1991 - 2005) due to the limited availability of data needed for the lower boundary condition in SWAP-PEARL (see section 5.2 in Tiktak et al., 2012b)[16].

6.3 Details of the different calculations

Example calculations were done with the Dutch upwards and sideways spraying scenario for three substances in apples. The substances were selected by the working group in collaboration with the Ctgb and based on currently registered products. The dose and application pattern selected for each substance is considered representative for the Dutch agricultural practice in orchards. The most relevant substance properties and the application scheme for each substance is given in Table 6. The full list of substance properties are given in Annex 6. Each substance is applied on a field with a total crop-free zone of 3 m and using a DRT class 90 spray technique (one of the minimum requirement options following the Environmental Activity Decree; MinI&W, 2021). When relevant, additional calculations were performed using either other scenario settings (DRT class 99) or different substance properties (a different value for the half-life in water of the considered substance).

Table 6 *Substance, doses and application patterns used for the example calculations.*

Substance	I_n	F	I_p
Substance type	insecticide	fungicide	insecticide
Substance group	neonicotinoid	phthalimide	pyrethroid
Crop	apples	apples	apples
Application times and doses[17]	1x 0.15 kg/ha, BBCH 61 (day 113 - 23 April),	15 x 1.8 kg/ha, start BBCH 68 (day 120 – 30 April) - 7 days interval	3 x 0.0075 kg/ha start BBCH 69 - 7 days interval: 29 April (day 119), 6 May (day 126), 13 May (day 133)
$DegT_{50,soil}$ (d)	118	3.82	50
$DegT_{50,water}$ (d)	1000	0.2 d at pH 7, 25C	1000
$DegT_{50,sediment}$ (d)	1000	1000	1000
Kom_{soil} (L/kg)	131	56.3	138820

Results of the example calculations are given in the following sections.

In each section the following standard graphs for the target stretch of the scenario ditch are presented:

- The average water concentration of dissolved substance over the 100 m target stretch as function of time for the 15 evaluation years (1991 – 2005); for both DRT90 and DRT99 and a total crop-free zone of 3m,
- The annual maximum water concentration of dissolved substance (PEC_{max}) per year for the 15 evaluation years; for both DRT90 and DRT 99 and a total crop-free zone of 3m,
- The average water concentration of substance dissolved over the 100 m target stretch as function of time for the selected target year only; for both DRT90 and DRT 99 and a total crop-free zone of 3m,

Also, cumulative monthly mass balance terms are given for the 15 evaluation years (1991 – 2005); for DRT90 and a total crop-free zone of 3 m. In a subsequent sub-section additional graphs that provide more insight (e.g. in specific sensitivities) are given.

Note that average concentrations of dissolved substance in the water layer of the target stretch of the scenario ditch are reported (so, the concentrations do not include the mass of substance adsorbed to suspended solids). Also, the concentrations were averaged over the 100 m target stretch of the ditch.

---

[16] Calculations were done with the following model versions: xSPEXUS version 1.4, SWAP version 3237, PEARL version 3.2.17.7 and TOXSWA model version: 3.3.7-A created on 22-Feb-2021.

[17] For the BBCH-day-of-year relation used see Table 7 and 8 in Van de Zande et al., 2019, and Annex 3 in Holterman et al. 2018).

6.4 Substance I_n in apples

6.4.1 Standard graphs

Substance I_n is a neonicotinoid which is applied once in apples in April[18]. Figure 29 shows the average concentration (dissolved) of substance I_n in the water of the 100 m target stretch as function of time for the evaluation period 1991 – 2005 for two classes of Drift Reducing Technology (DRT90 and DRT99). For most of the simulated years the figure shows large needle-shaped concentration patterns in spring (exceptions are 1994, 1995, 1998, 1999, 2001 and 2003). These are peak concentrations which are caused by spray drift. Spray drift is calculated with the xSPEXUS model according to the procedure explained in Chapter 3. Spray drift deposits are variable in time and in some years drift deposits are zero, when the wind is not directed towards the ditch at the time of application. Compared to the DRT90 results, the peak concentrations as result of spray drift for DRT99 are on average about a factor 4 lower. The needle-shaped pattern indicates that the substance quickly disappears out of the water layer of the ditch. Given that degradation is slow this must be caused by transport out of the ditch. This is supported by the monthly mass balances of the target stretch of the ditch shown in Figure 34, i.e. main processes of water leaving the target stretch of the ditch are outflow at either x = 100 m or at x = 200 m (note that water flow direction alternates during the simulation period).

Furthermore, Figure 29 shows that occasionally and during distinctive periods simulated concentrations for DRT90 and DRT99 are the same (e.g. 1994 -1995, autumn 1998 - 1999). In these periods concentrations are driven by drainage events. I_n is a relatively mobile and persistent substance. The substance is expected to leach to the drainpipes over a time period of months and drain emission is very likely to happen in the autumn of the year of application and/or in spring the following year.

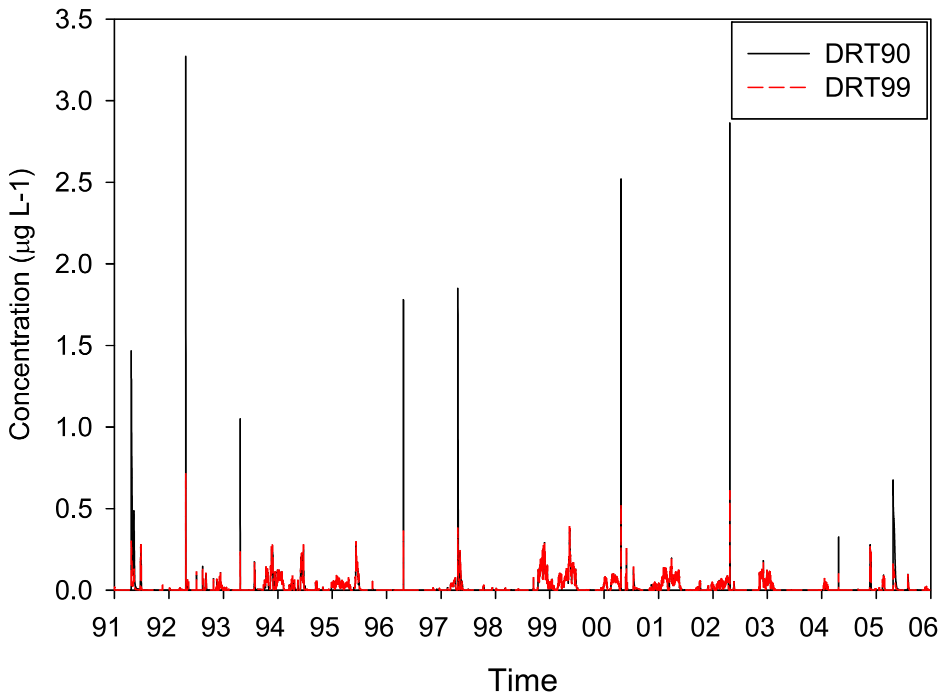

Figure 29 *Average concentration (dissolved) of substance I_n in the water of the 100 m target stretch as function of time for the evaluation period 1991 – 2005 for two classes of Drift Reducing Technology (DRT).*

[18] This is just an example substance to illustrate the developed procedure and outcomes. Neonicotinoids are not authorized anymore in the Netherlands in fruit orchards.

Figure 30 shows the annual maximum concentration (dissolved) of substance I_n in the water of the 100 m target stretch for DRT90 and DRT99. The blue arrows indicate the annual PEC_{max} value of the corresponding target temporal percentile, which was for both DRT90 and DRT99 the 63rd percentile.

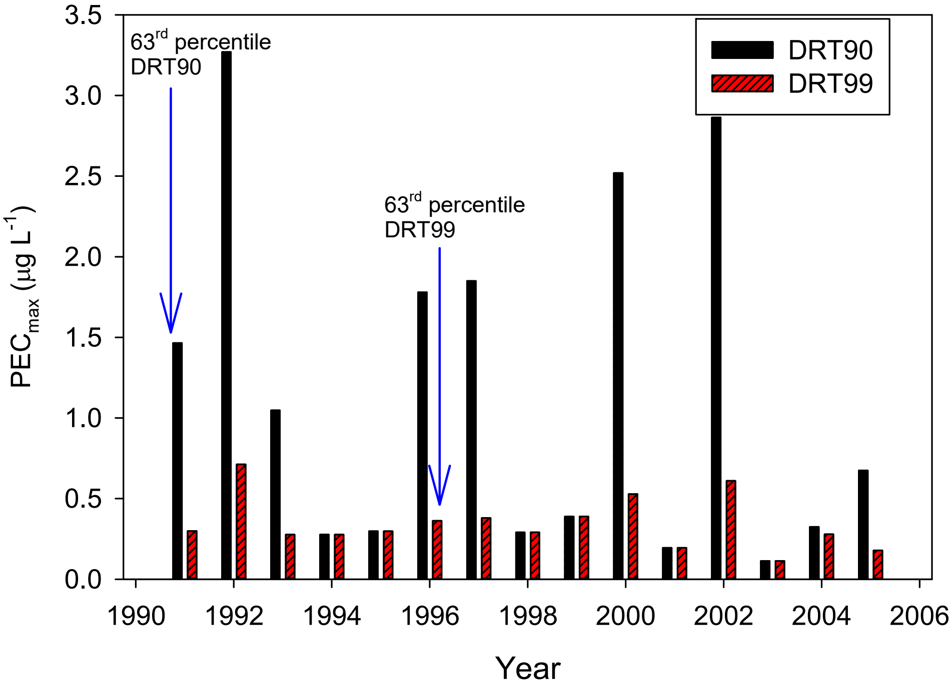

Figure 30 *Annual maximum concentration (dissolved) of substance I_n in the water of the 100 m target stretch for two classes of Drift Reducing Technology (DRT). The arrows indicate the 58.6th and 63rd percentile the annual maximum concentration for respectively DRT90 and DRT99.*

In Figure 31 and Figure 32 all calculated annual PEC_{max} values from the TOXSWA summary output file are given for the simulation with DRT90 and DRT99, respectively. Based on the application date and Figure 29, it was identified whether the PEC_{max} was caused by drainage or by spray drift[19]. For the simulation with DRT90, 6 PEC_{max} values are caused by drainage and 9 are caused by spray drift. For the simulation with DRT99, 8 PEC_{max} values are caused by drainage and 7 are caused by spray drift. According to the procedure described in Section 4.3 having 8 out of 15 years is not enough to decide for one of the routes being clearly dominant. Instead, the higher T90 of the two routes must be selected, which in this case is that for drainage (63%). Note that for both DRT90 and DRT99 in the 63rd percentile year (1991 and 1996 respectively), the PEC_{max} is delivered by spray drift.

[19] This was done by checking whether on the day of the PEC_{max} there is a drift event or a drain flow event. If both occur the dominant one is indicated.

```
* Percentile summary for substance In
* --------------------------------------------------------
* Rank  Percent    Yearly max.     Date of maximum
                   Concentration
                   dissolved
*  (-)      (%)     (µg.L-1)
*
* --------------------------------------------------------
1     3.33       0.1138     2003-01-13-23h00     drainage
 2     10.00      0.1946     2001-03-29-01h00     drainage
 3     16.67      0.2770     1994-06-21-07h00     drainage
 4     23.33      0.2902     1998-11-27-05h00     drainage
 5     30.00      0.2972     1995-06-10-11h00     drainage
 6     36.67      0.3245     2004-04-23-09h00     drift
 7     43.33      0.3885     1999-05-13-11h00     drainage
 8     50.00      0.6740     2005-04-23-09h00     drift
 9     56.67      1.0489     1993-04-23-09h00     drift
10     63.33      11.465     1991-04-23-09h00     drift
11     70.00       1.780     1996-04-23-09h00     drift
12     76.67       1.850     1997-04-23-09h00     drift
13     83.33       2.519     2000-04-23-09h00     drift
14     90.00       2.863     2002-04-23-09h00     drift
15     96.67       3.270     1992-04-23-09h00     drift

* The peak concentration dissolved in the water layer of In
* selected to represent the 63rd percentile is 1.465 ug/L and is found on
1991-04-23

* End of TOXSWA REPORT: Exposure concentration in water layer
* ---------------------------------------------------------------------------
```

Figure 31 *Information on the annual PEC_{max} concentrations in the target stretch of the ditch extracted from the *.sum output file of TOXSWA; simulation with substance I_n and* *<u>DRT90</u>*. *The last column is added manually and indicates the dominant source for the PEC_{max}.*

```
* Percentile summary for substance In
* ---------------------------------------------------------------
* Rank  Percent    Yearly max.     Date of maximum
                   Concentration
                   dissolved
*  (-)      (%)     (µg.L-1)
*
* ---------------------------------------------------------------
    1      3.33      0.1138     2003-01-13-23h00  drainage
    2     10.00      0.1782     2005-04-23-09h00  drift
    3     16.67      0.1946     2001-03-29-01h00  drainage
    4     23.33      0.2768     1993-11-24-23h00  drainage
    5     30.00      0.2769     1994-06-21-07h00  drainage
    6     36.67      0.2783     2004-11-20-23h00  drainage
    7     43.33      0.2902     1998-11-27-05h00  drainage
    8     50.00      0.2971     1995-06-10-11h00  drainage
    9     56.67      0.2982     1991-04-23-09h00  drift
   10     63.33      0.3617     1996-04-23-09h00  drift
   11     70.00      0.3793     1997-04-23-09h00  drift
   12     76.67      0.3885     1999-05-13-11h00  drainage
   13     83.33      0.5274     2000-04-23-09h00  drift
   14     90.00      0.6095     2002-04-23-09h00  drift
   15     96.67      0.7129     1992-04-23-09h00  drift

* The peak concentration (dissolved) in the water layer of In
* selected to represent the 63rd percentile is 0.3617 ug/L and is found on
1996-04-23

* End of TOXSWA REPORT: Exposure concentration in water layer
* ---------------------------------------------------------------------------
```

Figure 32 *Information on the annual PEC_{max} concentrations in the target stretch of the ditch extracted from the *.sum output file of TOXSWA; simulation with substance I_n and* *<u>DRT99</u>*. *The last column is added manually and indicates the dominant source for the PEC_{max}.*

Figure 33 shows the concentration patterns for DRT90 and DRT99 in the year of the required target percentile. Both PEC_{max} values are found on the day of application, however, the PEC_{max} for DRT99 is roughly a factor 4 lower than the one for DRT90.

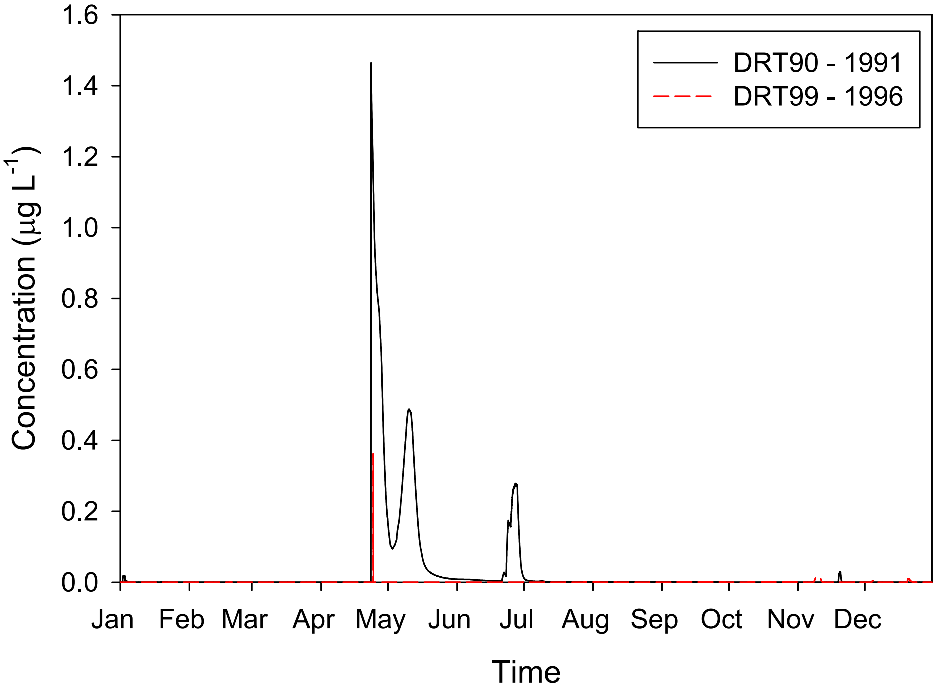

Figure 33 *Average concentration (dissolved) of substance I_n in the water of the 100 m target stretch as function of time for the year in which the target percentile is found (1991 for DRT90 and 1996 for DRT99).*

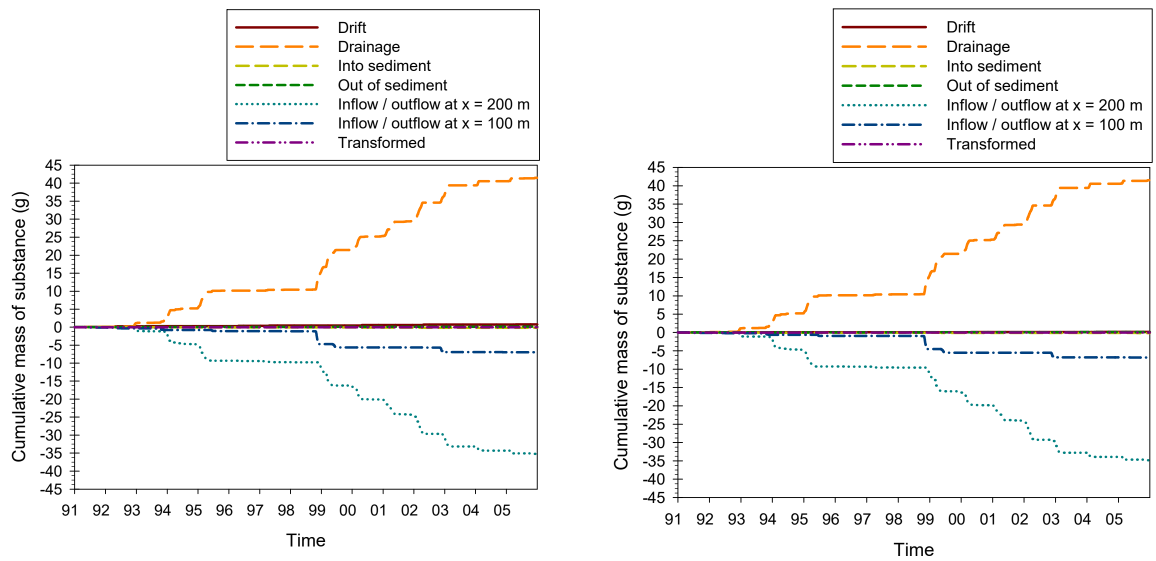

Figure 34 *Cumulative mass balances of substance I_n for DRT90 (left hand side) and DRT99 (right hand side). Negative values indicate a sink and positive values a source. Note, that due to varying flow directions substance may both enter the target stretch (inflow) or leave the target stretch (outflow) via the boundaries of the target stretch (x = 100m and x = 200m).*

Figure 34 shows that during the 15 years evaluation period, the largest part of the mass of substance I_n enters the ditch by drainage and not by spray drift. However, for DRT90 the annual PEC_{max} is in only 6 out of 15 years the result of drainage. This is because concentration in the drainage water is not high compared to the peak concentration in the ditch caused by spray drift. The volume of drainage water entering the ditch is often large and therefore the total mass of I_n entering the ditch by drainage is much larger than the mass entering the ditch by spray drift.

Figure 34 also shows that, for the 100m as well as for the 200m boundary of the target stretch, the inflow/outflow lines are negative and thus in both cases the outflow of mass exceeds the inflow of mass. Moreover, the outflow at x = 200m is significantly larger than the outflow at x = 100m.

Differences in the mass balances of DRT90 and DRT99 are found in spray drift deposition. For DRT90 the mass entering the ditch via spray drift is larger than for DRT99. Note further that emission from drains is erratic, in some of the simulated years the inflow via drain flow is almost zero, as can be seen from the nearly horizontal lines during 1996-1999.

Substance I_n mainly leaves the ditch via outflow of water (Figure 34). Degradation half-lives in water and sediment were set to 1000 d, so degradation is negligible. The sorption coefficient for sediment ($K_{om,sed}$) was assumed to be the same as the $K_{om,soil}$, namely 131 L kg^{-1}. This is a low value with respect to pesticide fate in surface water and I_n mass transports into and out of the sediment are therefore minor parts of the mass balance.

6.4.2 Additional analysis

What is the contribution of the spray drift to PEC_{max}?
Additional graphs were made to check to what extent the annual PEC_{max} is caused by spray drift or by drainage input.

The top graph of Figure 35 shows the results for the calculations with DRT90. The calculated water concentration is plotted against spray drift deposition as percentage of the dose. Annual PEC_{max} values caused by drainage are found in years without a spray drift event; i.e. these are the dots situated on the y-axis (the annual maximum spray drift percentage is zero).

For the years where the annual PEC_{max} values are caused by spray drift the relationship between the annual PEC_{max} and the annual drift deposition is nearly linear. This points towards the following two aspects:

i. The concentration in the ditch is predominantly caused by spray drift i.e. at the moment of the spray drift event (23 April) there is no or little substance mass in the water layer of the ditch due to drainage. Note that: Although I_n is a rather persistent substance ($DegT_{50,soil}$ of 118 d), it is also a relatively mobile substance ($K_{om,soil}$ of 131 L/kg) which means that I_n leaches relatively quickly to the drains.
ii. The degree of dilution in the ditch is rather constant meaning that the water depth fluctuation in the ditch is small (see also Ter Horst et al., 2020: the water depth fluctuates between 26 and 43 cm with a 50th percentile of about 28 cm and a 90th percentile of about 29 cm in summer[20] and 31 cm in winter[21]. So, dilution of the spray drift deposits can maximally approach a factor of 2, i.e. 43/26, but is generally far less.).

Deviation from the linear relationship can either be caused by a strong deviation from the median water depth or by substance mass due to drain flow present in the ditch at the time of the spray drift event. The latter was checked by inspecting the concentration patterns around the date of the annual spray drift events. The initial mass present was not significant for the DRT90 run. The three but highest spray drift deposition results in a lower annual PEC_{max} value, that visibly deviates from the straight line, indicating that the water depth was relatively high at the moment of application, namely 38 cm.

For the DRT99 run, which is shown in the bottom graph of Figure 35, there are again a number of annual PEC_{max} values where the spray drift deposition was zero (the 6 dots located on the y-axis in the

[20] 1 April- 30 September.
[21] 1 October – 31 March.

bottom graph of Figure 35) and thus for which the annual PEC_{max} values are caused by drainage entries. In addition, two annual PEC_{max} values (dots encircled with a blue coloured line) are located above the straight line that could be drawn through the remaining dots, so in these cases the annual PEC_{max} values are caused either by an addition of the spray drift deposition on remaining drainage entries in the ditch at the time of drift deposition or by the drainage entries alone. The latter was checked to be the case and thus, although drift deposition did happen in those three years, the drainage entries caused the highest peak concentrations. Note further there is one annual PEC_{max} value (at annual maximum spray drift percentile around 0.7) that is lower than the straight line and, similar to the DRT90 situation, this is caused by a relatively high water depth (38 cm).

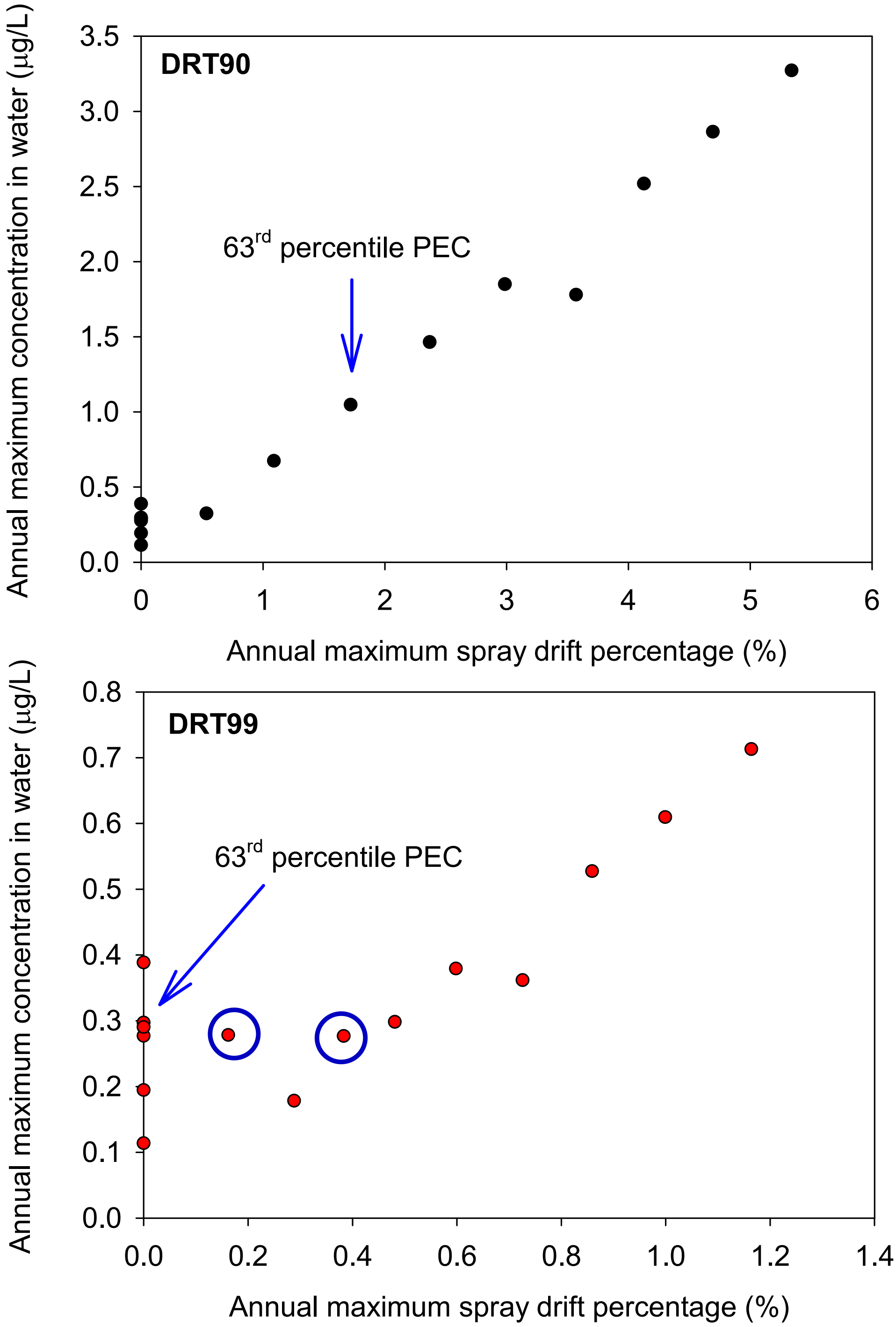

Figure 35 *Annual maximum concentration in water (PEC_{max} in µg L^{-1}) as function of the spray drift deposition (percentage of the applied dose) for DRT90 (top graph) and DRT99 (bottom graph). The dots encircled in the DRT99 plot indicate PEC_{max} values caused by drainage in years that spray drift deposition was less than the peak drainage entries.*

Summarizing, there is a considerable chance that the wind is directed away from the ditch at the time of the application and hence that the drift deposition after application is zero and drain emission is automatically dominant. In most other situations the annual PEC_{max} values are caused by spray drift. An exception is the DRT99 application for which the drainpipe emissions dominated the (non-zero) spray drift deposition, as was shown above for three annual PEC_{max} values.

6.5 Substance F in apples

6.5.1 Standard graphs

As described before fungicide F is applied 15 times on apples, from 30 April onwards and with intervals of 7 days.

Figure 36 shows the average concentration (dissolved) of substance F in the water of the 100 m target stretch as function of time for the evaluation period 1991 – 2005 for two classes of Drift Reducing Technology (DRT90 and DRT99). For each year a set of peak concentrations is observed, mainly in the period May-June. These peak concentrations are caused by spray drift deposition, that are higher in this period than later in the year, when the canopy density has substantially increased. In periods of coinciding concentration patterns of DRT90 and DRT99 concentrations are driven by drainage events, that do not depend on the drift reducing application technique (e.g. end of 1993, 1999 and 2002).

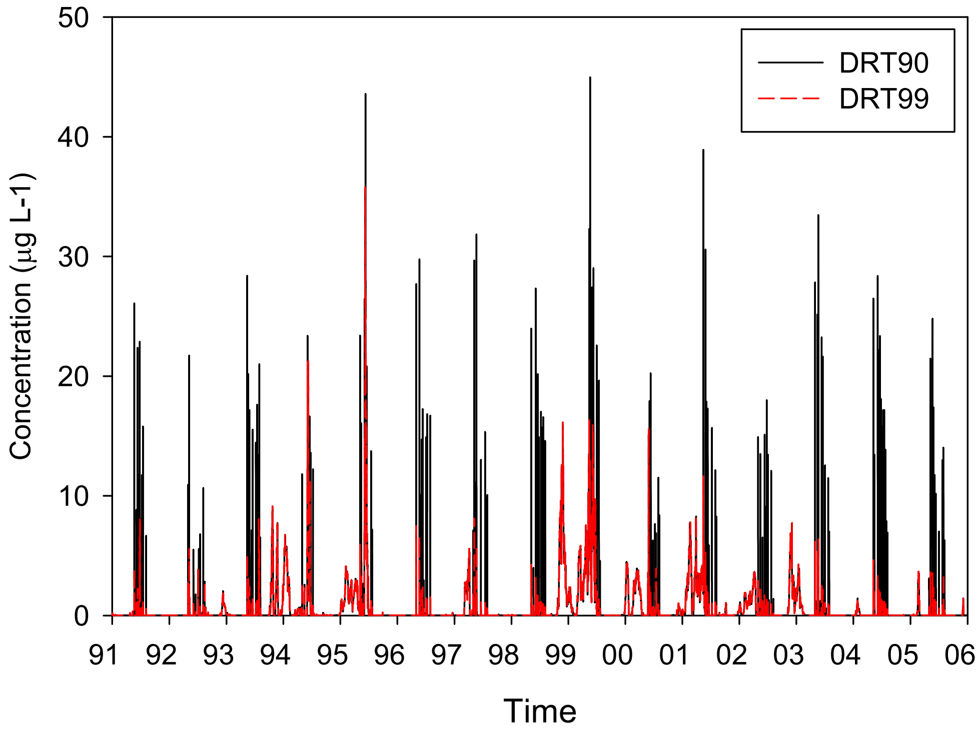

Figure 36 *Average concentration (dissolved) of substance F in the water of the 100 m target stretch as function of time for the evaluation period 1991 – 2005 for two classes of Drift Reducing Technology (DRT).*

Annual maximum concentrations (dissolved) of substance F in the water of the 100 m target stretch (PEC_{max}) for DRT90 and DRT99 are presented in Figure 37. The blue arrows in Figure 37 indicate the annual PEC_{max} value of the required target percentile. For the DRT90 run, the required target percentile is the 16.7th percentile from the spray drift entry route. For the DRT99 run, the required target percentile is the 63rd percentile from the drainage entry route.

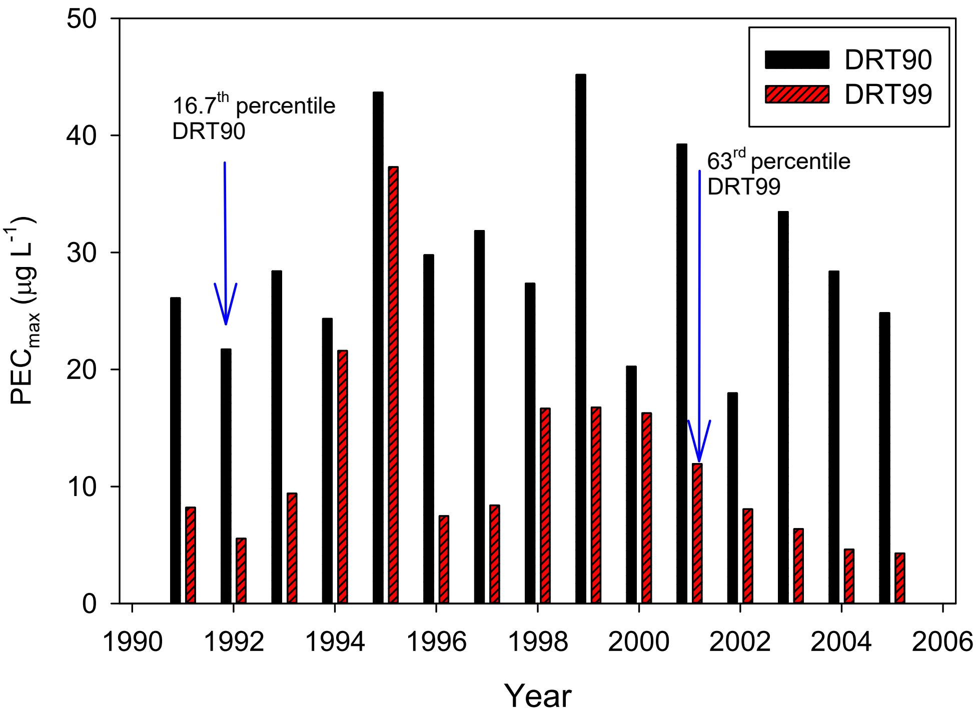

Figure 37 *Annual maximum concentration (dissolved) of substance F in the water of the 100 m target stretch for two classes of Drift Reducing Technology (DRT). The arrows indicate the 16.7th percentile annual maximum concentration for the DRT90 and the 63rd percentile annual maximum concentration for the DRT99.*

For DRT90, all PEC_{max} values were caused by spray drift which corresponds to a T90 which is the 16.7th percentile. The 16.7th percentile of the 15 annual PEC_{max} values is found in the year 1992. For the simulation with DRT99, 9 PEC_{max} values are caused by drainage and 6 are caused by spray drift. According to the procedure described in Section 4.3 having 9 out of 15 years is not enough to decide for one of the routes being clearly dominant. Instead, the higher T90 of the two routes must be selected, which in this case is that for drainage (63 percentile). The 63rd percentile of the 15 annual PEC_{max} values is found in the year 2001. Inspection of the relevant parts of the summary output file of TOXSWA shows that both PEC_{max} values for DRT90 and DRT99 are found on a day where spray is applied. This points towards a peak concentration predominantly caused by spray drift. However, this does not necessarily mean that the annual PEC_{max} is exclusively the result of spray drift, drainage entries may have contributed to the peak concentration. Analysis of the concentration pattern around the date of the PEC_{max} for DRT90 confirmed that the 16.7th percentile PEC_{max} value was caused by spray drift only, as there was no 'background concentration' in the ditch at the time of the peak at 7 May 1992 (Figure 40). However, the concentration pattern for DRT99 around the date of the peak concentration of 14 May 2001 shows that there was a 'background concentration' in the ditch on top of which the spray drift was deposited, so in this case the annual PEC_{max} value was indeed not exclusively caused by the spray drift entry. This has been indicated in Figure 38 and Figure 39. Figure 40 shows the concentration patterns for DRT90 and DRT99 in the year of the required target percentile. The PEC_{max} value of DRT90 is found on 7 May (1992) and the PEC_{max} value of DRT99 is found on 14 May (2001). The PEC_{max} for DRT99 is about a factor 2.5 lower. Figure 40 shows that the PEC_{max} of DRT99 has been caused by both spray drift and drainage.

```
* Percentile summary for substance F
* --------------------------------------------------------------
* Rank  Percent     Yearly max.     Date of maximum
                    Concentration
                    dissolved
*  (-)       (%)      (µg.L-1)
*
* --------------------------------------------------------------
 1      3.33       17.98     2002-06-25-09h00    drift
 2     10.00       20.23     2000-06-11-09h00    drift
 3     16.67       21.72     1992-05-07-09h00    drift
 4     23.33       24.33     1994-06-04-09h00    drift
 5     30.00       24.82     2005-05-21-09h00    drift
 6     36.67       26.09     1991-05-21-09h00    drift
 7     43.33       27.33     1998-06-04-09h00    drift
 8     50.00       28.38     2004-06-04-09h00    drift
 9     56.67       28.39     1993-05-14-09h00    drift
10     63.33       29.76     1996-05-21-09h00    drift
11     70.00       31.83     1997-05-21-09h00    drift
12     76.67       33.47     2003-05-21-09h00    drift
13     83.33       39.24     2001-05-14-09h00    drift
14     90.00       43.67     1995-06-11-09h00    drift
15     96.67       45.18     1999-05-21-09h00    drift
* The peak concentration (dissolved) in the water layer of F
* selected to represent the 16.70th percentile is 21.72 ug/L and is found on
1992-05-07

* End of TOXSWA REPORT: Exposure concentration in water layer
* ------------------------------------------------------------------------
```

Figure 38 *Information on the annual PEC_{max} concentrations in the target stretch of the ditch extracted from the *.sum output file of TOXSWA; simulation with substance F and DRT90. The last column is added manually and indicates the dominant source for the PEC_{max}[22].*

```
* Percentile summary for substance F
* --------------------------------------------------------------
* Rank  Percent     Yearly max.     Date of maximum
                    Concentration
                    dissolved
*  (-)       (%)      (µg.L-1)
*
* --------------------------------------------------------------
   1      3.33       4.288     2005-02-21-23h00    drain
   2     10.00       4.620     2004-05-07-09h00    drift
   3     16.67       5.543     1992-05-07-09h00    drift
   4     23.33       6.363     2003-05-21-09h00    drift
   5     30.00       7.479     1996-04-30-09h00    drift
   6     36.67       8.071     2002-12-04-03h00    drain
   7     43.33       8.190     1991-06-27-23h00    drain
   8     50.00       8.392     1997-05-07-09h00    drift
   9     56.67       9.408     1993-10-22-23h00    drain
  10     63.33       11.94     2001-05-14-09h00    drift
  11     70.00       16.26     2000-05-29-09h00    drain
  12     76.67       16.66     1998-11-27-05h00    drain
  13     83.33       16.75     1999-05-14-09h00    drift
  14     90.00       21.59     1994-06-09-05h00    drain
  15     96.67       37.30     1995-06-10-07h00    drain

* The peak concentration (dissolved) in the water layer of F
* selected to represent the 63rd percentile is 11.61 ug/L and is found on
2001-05-14

* End of TOXSWA REPORT: Exposure concentration in water layer
* ------------------------------------------------------------------------
```

Figure 39 *Information on the annual PEC_{max} concentrations in the target stretch of the ditch extracted from the *.sum output file of TOXSWA; simulation with substance F and DRT99. The last column is added manually and indicates the dominant source for the PEC_{max}.*

[22] Which source is ‘dominant’ was assessed by applying the procedure specified in section 4.3 and Annex 2.

Note that in Figure 39 most of the higher percentile annual PEC_{max} values are caused by drainage. For the DRT99 application technique of this example calculation drainage is an important entry route due to the relatively low sorption coefficient of substance F (K_{om} = 56.3 L/kg) and the high number of 15 applications.

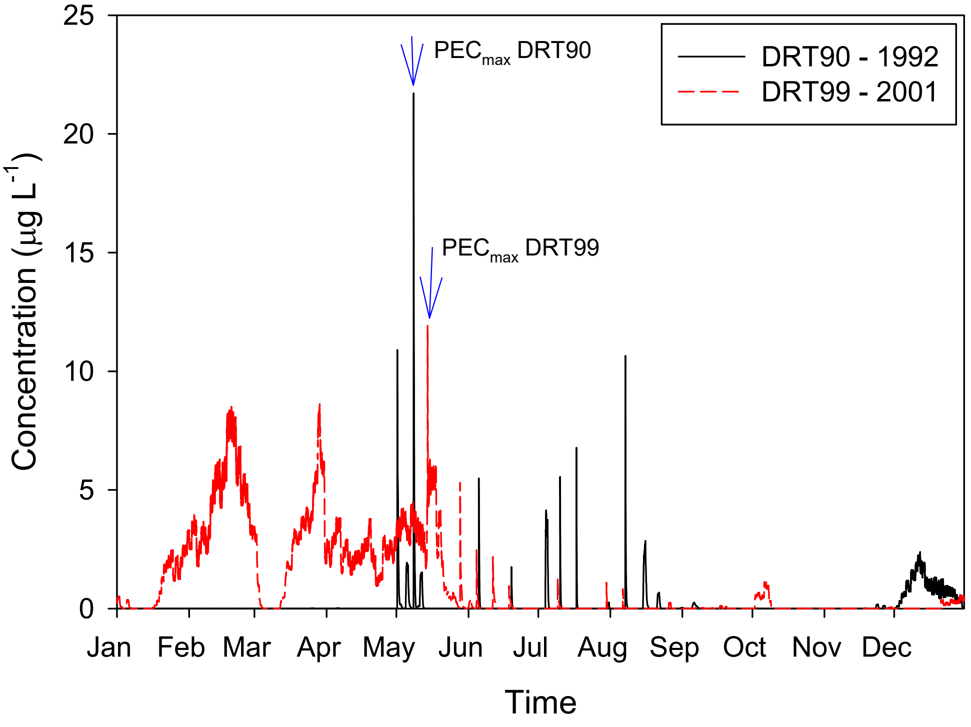

Figure 40 *Average concentration (dissolved) of substance F in the water of the 100 m target stretch as function of time for the year in which the target percentile is found (1992 for DRT90 and 2001 for DRT99).*

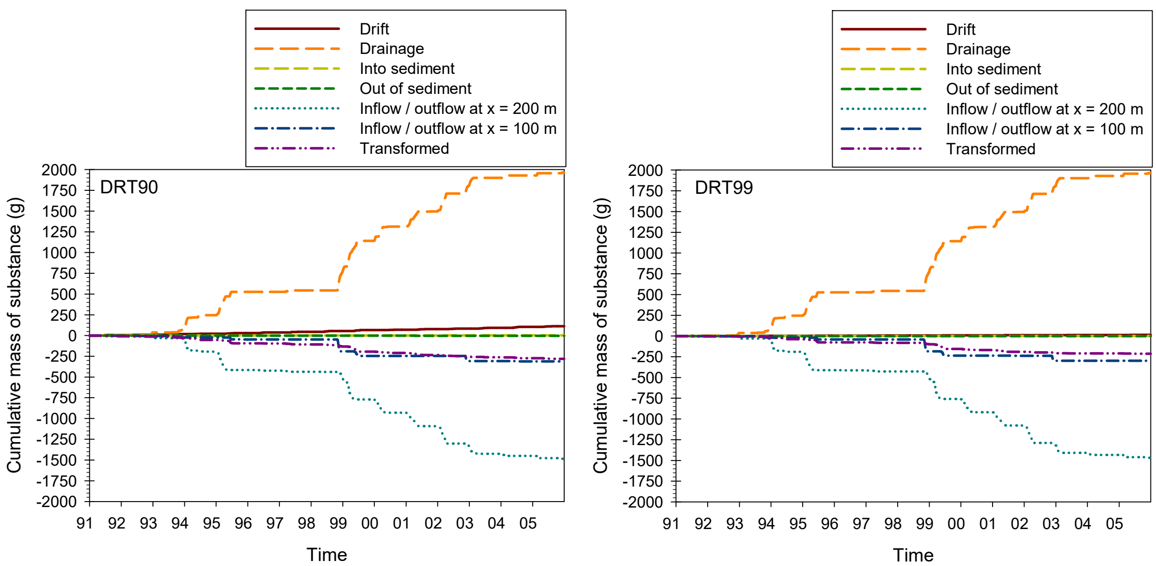

Figure 41 *Cumulative monthly mass balances of substance F for DRT90 (left hand side) and DRT99 (right hand side). Negative values indicate mass transport out of the water layer. Note, that due to varying flow directions substance may both enter the target stretch (inflow) or leave the target stretch (outflow) via the boundaries of the target stretch (x = 100m and x =200m).*

Similar to the example of substance I_n, the largest part of the mass of substance F enters the ditch by drainage and not by spray drift (Figure 41). The amount of drainage water entering the ditch is often large leading to a much higher total mass of F entering the ditch by drainage than by spray drift. Outflow of water is largely responsible for the disappearance of substance F from the water layer of the target stretch of the scenario ditch. For the 100m as well as the 200m boundary of the target stretch, the inflow/outflow lines are negative and thus in both cases the outflow of mass dominates the inflow of mass. Moreover, the outflow at x = 200m is significantly larger than the outflow at x = 100m. Contrary to substance I_n, transformation in the water clearly contributes to the disappearance of substance F from the water layer (degradation half-live in water of 0.2 d). Transports in and out of the sediment of substance F are minor parts of the mass balance. This is explained by the low value of the sorption coefficient for sediment ($K_{om,sed}$) which was assumed to be the same as the $K_{om,soil}$, namely 56.3 L kg^{-1}.

6.5.2 Additional analysis

Is there accumulation of substance F in water for 15 applications with an interval of 7 days?
Based on the rationale that the residence time is low in the evaluation ditch and hence accumulation of substance in water will play a minor role, accumulation was not considered in the scenario derivation for drift deposition (Chapter 3).

An additional simulation was performed with a more persistent substance F, i.e. with the half-life in water increased from 0.2 d to 1000 d, for DRT90 applications. Next, the annual PEC_{max} values of both simulations with a short and a long DT50 were compared (Figure 42). In all years except two (1994 and 1995) the differences between the peaks of the persistent and non-persistent substance F are relatively small and thus, in most cases accumulation of mass in water (by spray drift deposits as well as by drainage entries) plays a minor role in the scenario selection procedure. For two of the 15 years the annual PECmax values of the persistent and non-persistent substance are very different. These differences are probably due to the considerable drainage for the persistent substance in those years. For both the persistent and non-persistent substance F, drainage emission in to the ditch is similar. Generally, the mass entering the evaluation ditch via drain emission is large due to the high application rate of 1.8 kg/ha, significant leaching by the low Kom value and 15 applications that compensate for the short degradation half-life in soil of 3.82 d. In 1994 and 1995 the mass entering the evaluation ditch via drain emission is enlarged due to the many drain events. In these years, the sustained drainage entries, that do not degrade in the ditch water for the persistent substance F, may contribute to the annual PECmax values.

Concentrations in the target stretch of the evaluation ditch of both simulations were plotted as function of time for the year 2004. The year 2004 has many non-zero spray drift events and negligible drainage in the period 30 April – 6 August (Figure 43). Both substances, the persistent and the non-persistent, have the same maximum peak concentration. For the persistent substance, the concentrations decrease less quickly than the ones of the non-persistent substance. However, after seven days (i.e. the application interval) the concentrations are so low that the peak concentrations as result of the subsequent drift events are nearly similar for the persistent and the non-persistent substance. Some accumulation can be seen in the first two weeks op July.

So, it can be concluded that the effect of the accumulation in case of multiple applications per year is low. This is in line with the spray drift scenario selection procedure (Section 3.4.2).

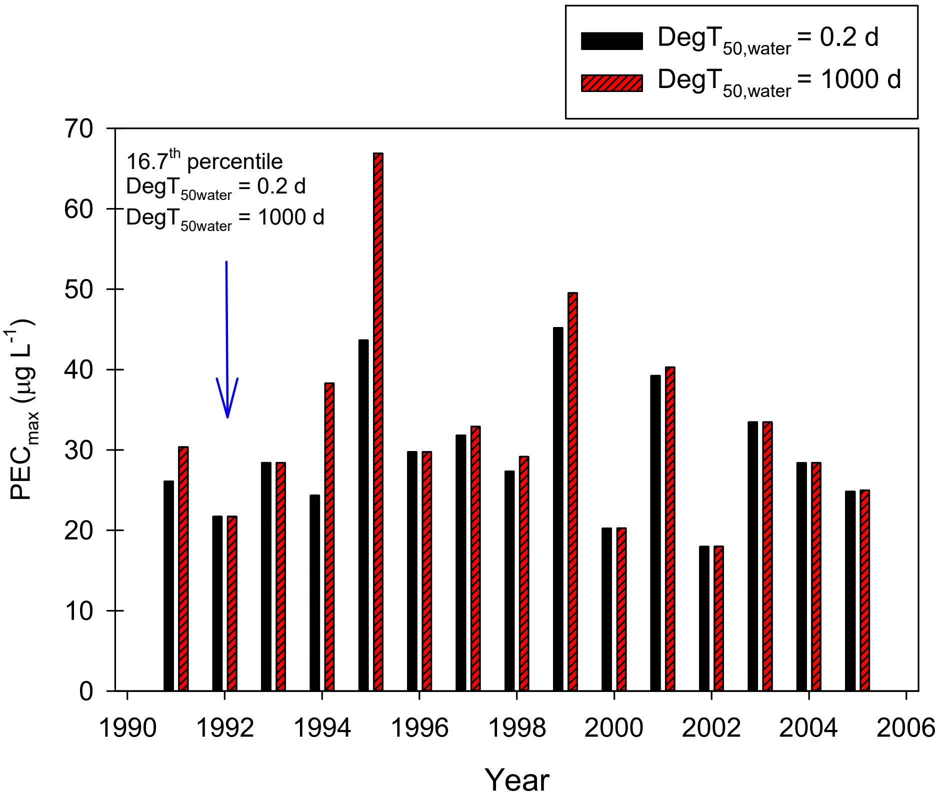

Figure 42 *Annual maximum concentration (dissolved) of substance F, in the water of the 100 m target stretch for two different values of the half-life in water (0.2 d and 1000 d) (DRT90). The arrow indicates the 16.7th percentile annual maximum concentration.*

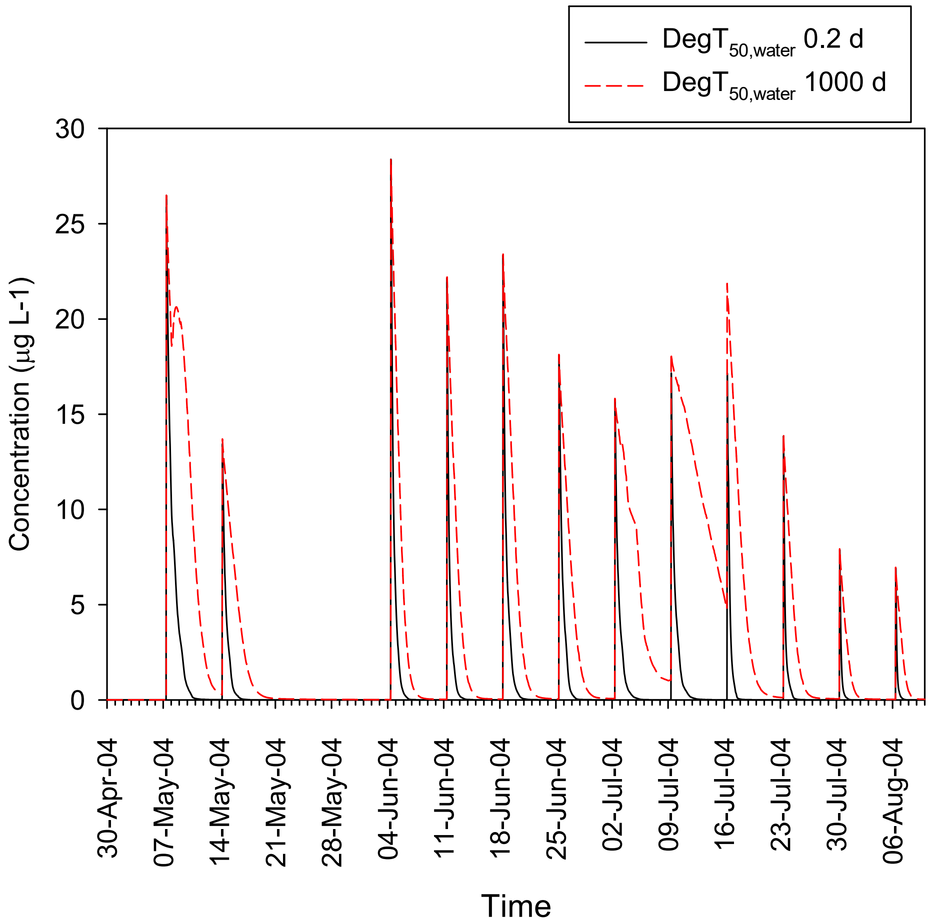

Figure 43 *Average concentration (dissolved) of substance F in the water of the 100 m target stretch as function of time for two different values of the half-life in water (0.2 d and 1000 d) and the year 2004 (DRT90).*

Contribution of drain emission to accumulation in water

Here we illustrate how a sustained drain flow containing pesticide mass may contribute to the annual PEC_{max} values. We do so for the year 1995, the year with the highest difference in peak concentrations for the persistent and non-persistent substance F (see Figure 45). The peak concentrations occurred in the period 12 May – 22 June 1995, which is a period with 6 applications and substantial concentrations and flow rates of the drain water (Figure 44). The pesticide is applied on the following dates. Note that not every application leads to a drift deposition event:

- 14 May (drift loading: 3.9 mg.m^{-2})
- 21 May (drift loading: 0 mg.m^{-2})
- 28 May (drift loading: 0.5 mg.m^{-2})
- 4 June (drift loading: 3.7 mg.m^{-2})
- 11 June (drift loading: 4.7 mg.m^{-2})
- 18 June (drift loading: 2.7 mg.m^{-2})

As can be seen from the difference between the two concentration profiles in Figure 45 accumulation of mass in the ditch water has a significant contribution to peak concentrations at 5 June, 10 and 12 June and 18 June of the persistent substance F. This is probably due to substance concentrations in the drain water and significant flow rates of the drain water a few days before or at the day of application (Figure 44). So, a considerable mass enters the ditch from the drains which does not degrade, due to the DT_{50} in water of 1000 d. This is added to the spray drift deposits at the dates of application. Note that although the concentration in the drainage water is very high on 17 May, 26 May and 2 June, this is not reflected in increased concentrations in the ditch water on these days. This is because the drainage flow rate on these days are very small and consequently the dilution in the ditch is very large.

So, here we illustrated how sustained drain flows may contribute to the annual peak concentrations in the ditch water, when the substance is not degraded. This does not invalidate the followed scenario selection procedure for spray drift entries.

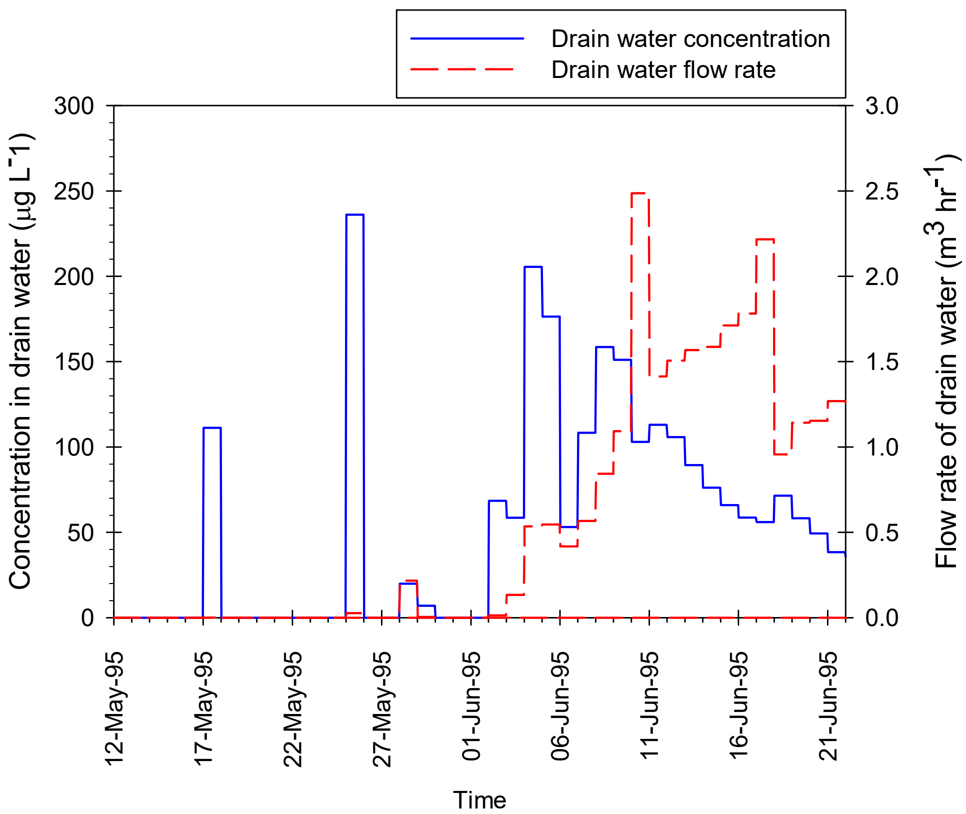

Figure 44 *Concentration of substance F in the drain water and flow rate of drain water entering the of the 100 m target stretch of the evaluation ditch.*

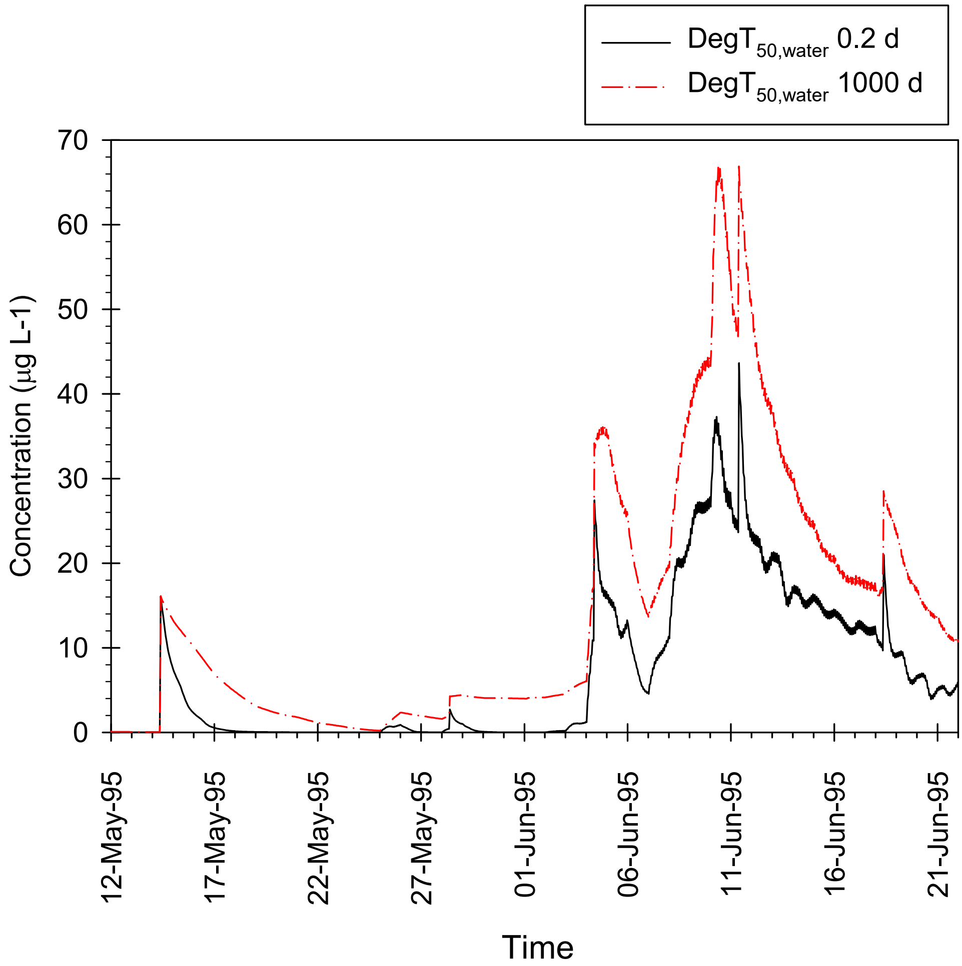

Figure 45 *Average concentration (dissolved) of substance F in the water of the 100 m target stretch as function of time for the period 12 May – 22 June 1995 for two different values of the half-life in water (0.2 d and 1000 d), (DRT90).*

Variability in canopy density visible in spray drift deposits reflected in the annual PEC_{max} caused by spray drift?

As described in Holterman et al. (2018) one of the major factors in the computation of the spray drift deposits with the SPEXUS model is the canopy density. Canopy density is low in winter, increases during spring to full density in summer and decreases again in autumn. When canopy starts to develop the interception of spray by the trees increases and consequently, spray drift deposits on the water surface of the ditch decrease. The means that PEC_{max} values should generally be lower in summer (July – August) than in spring (April – May). Figure 46-A shows an example of the drift deposition corresponding to PEC90 as percentage of the applied dose for the selected configuration and for a single application using DRT90 with 3 m total crop-free zone (also shown in Figure 18 in section 3.6).

The example calculation of substance F (DRT90) is suitable for verifying this hypothesis as it includes 15 weekly applications throughout the growing season (10 April - 6 August). Also, all of the annual PEC_{max} values are predominantly caused by spray drift (Figure 38). This means that all annual PEC_{max} values occur on an application day. For each year the application date was identified that corresponded to the maximum water concentration in that year (annual PEC_{max}; 15 in total, because there are 15 evaluation years). The number of PEC_{max} values found for each application date has been plotted in Figure 46-B. Hence, the application on the 21st of May caused a maximum concentration in 6 of the 15 simulated years. When comparing Figure 46-A with Figure 46-B, roughly the same pattern can be observed: all PEC_{max} values are found in the period May – June (i.e. during the period of the development of the canopy). During summer (July, August) when tree canopies are fully developed spray drift deposits on the water surface reach a minimum and consequently PEC_{max} values are unlikely to occur for applications in this period.

Concluding: the variability in crop density is reflected in the spray drift deposits on the ditch and also in the timings of the annual PEC_{max} values caused by spray drift.

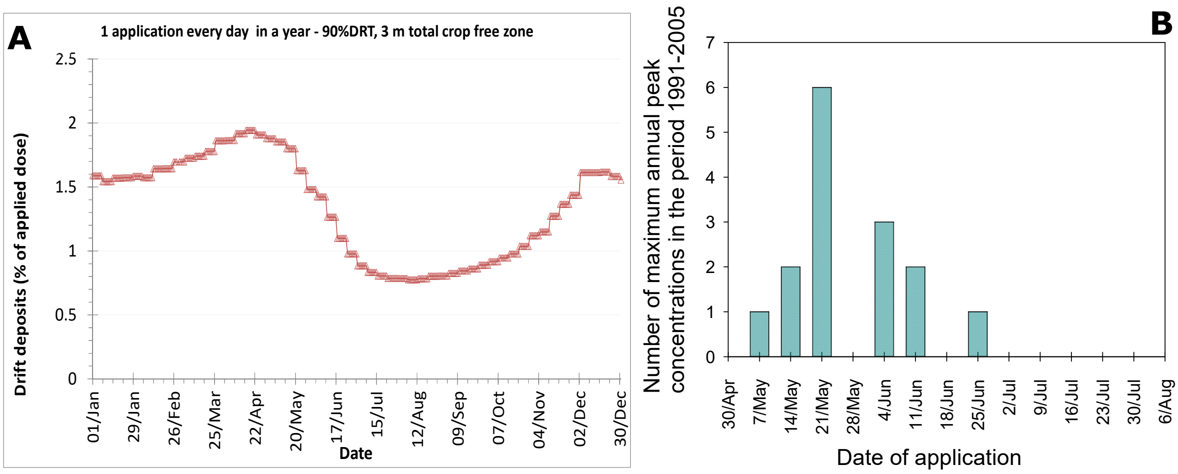

Figure 46 ***A**. Drift deposits (corresponding to PEC90) on an edge-of-field water course as function of time in a year for a single application with DRT90 and 3m of total crop-free zone. The graph is based on 365 simulations **B**. Number of PEC_{max} values occurring on each application date for 15 weekly applications on the dates mentioned on the x-axis in the period 30 April – 6 August.*

6.6 Substance I_p in apples

6.6.1 Standard graphs

Results of simulations of 3 annual applications (29 April, 6 May, 13 May) of substance I_p (pyrethroid) for DRT90 and DRT99 are presented. The substance has a high K_{om} value (138820 L/kg), half-life in soil of 59 d and does not degrade in water and sediment (Table 6).

Figure 47 shows the average concentration (dissolved) of substance I_p in the water of the 100 m target stretch as function of time for the evaluation period 1991 – 2005 for two classes of drift reducing techniques (DRT90 and DRT99). Nearly all the observed peak concentrations are caused by spray drift, as demonstrated by the needle shaped concentration profiles. Unlike substances I_n and F, increase of the concentration by drainage in autumn or winter is invisible.

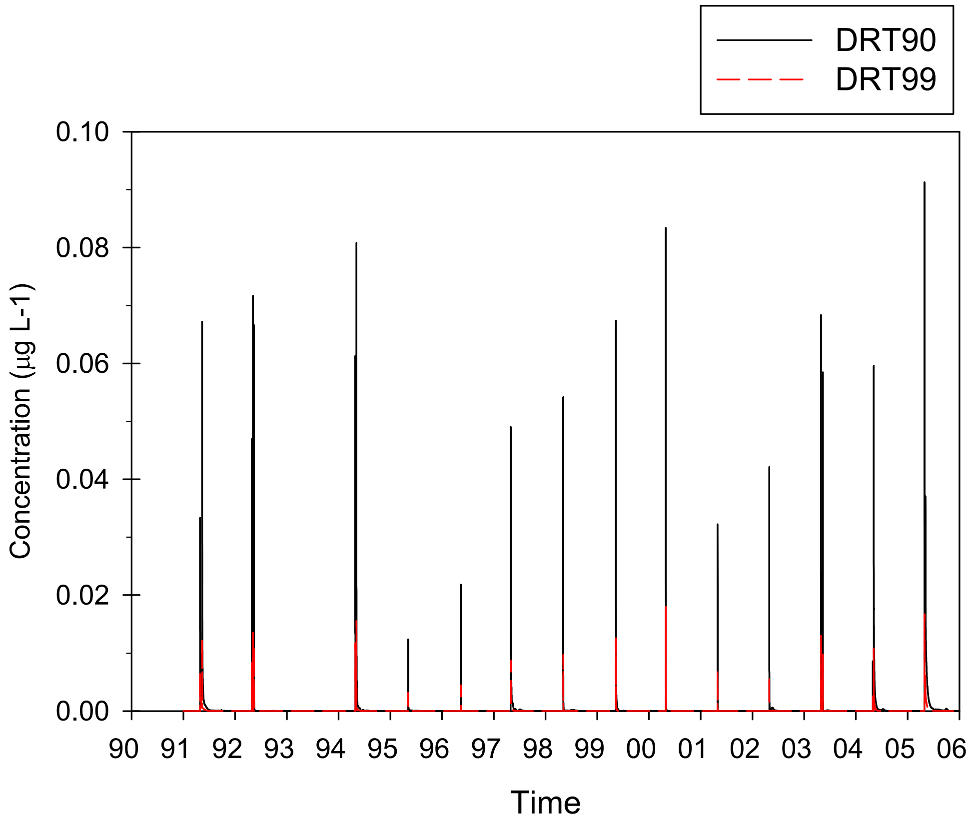

Figure 47 *Average concentration (dissolved) of substance I_p in the water of the 100 m target stretch as function of time for the evaluation period 1991 – 2005 for two classes of drift reducing techniques (DRT).*

Annual maximum concentration (dissolved) of substance I_p in the water of the 100 m target stretch for DRT90 and DRT99 are presented in Figure 48. The blue arrows in Figure 48 indicate the annual PEC_{max} value of the required target percentile. For the DRT90 simulation, the required target percentile is the 36.4th percentile from the spray drift entry route. For the DRT99 simulation, the required target percentile is the 38.4th percentile from the spray drift entry route. For both DRT90 and DRT99, the target percentile of the annual PEC_{max} values is found in the year 1997. Inspection of the relevant part of the summary output file of TOXSWA (Figure 49 and Figure 50) shows that both PEC_{max} values for DRT90 and DRT99 are found on a day of an application. This points towards a peak concentration predominantly caused by spray drift. Also, in 14 out of 15 years drift is recognized as the major entry route (Figure 49 and Figure 50).

This does not necessarily mean that the annual PEC_{max} is exclusively the result of spray drift. Drainage entries may contribute to the annual PEC_{max} values. Analysis of the output file of PEARL containing the drainage fluxes showed that on the date of the PEC_{max} a minor drainage event containing a negligible amount of substance occurred (drainage water flux of 0.18 m^3 hr^{-1} and concentration in drainage water of 6.7 E^{-6} µg m^{-3}). This implies that the target percentile PEC_{max} values for the DRT90 and DRT99 are indeed predominantly caused by spray drift. Figure 51 shows the concentration patterns for DRT90 and DRT99 in the year of the required target percentile (1997). Both PEC_{max} values are found on 29 April i.e. one of the three application dates. The PEC_{max} values for DRT99 are about a factor 5 to 6 lower than the PEC_{max} values for DRT90 (approximately 0.05 vs 0.009 µg/L). Contrary to the example cases of substances I_n and F, the largest part of the mass of substance I_p enters the ditch by spray drift and not by drainage (Figure 52). The reason is that substance I_p is a pyrethroid. Strong sorption to soil/sediment organic matter is typically for this type of compounds. The input of I_p via the drain is low because, only negligibly small quantities of I_p leach to the drains. Most I_p mass is adsorbed in the upper layers of the soil. For both graphs in Figure 52 the same scale is used on the y-axis to illustrate that the cumulative mass of the different mass balance terms is about a factor 5 lower for the DRT99 simulation, due to the reduction of spray drift.

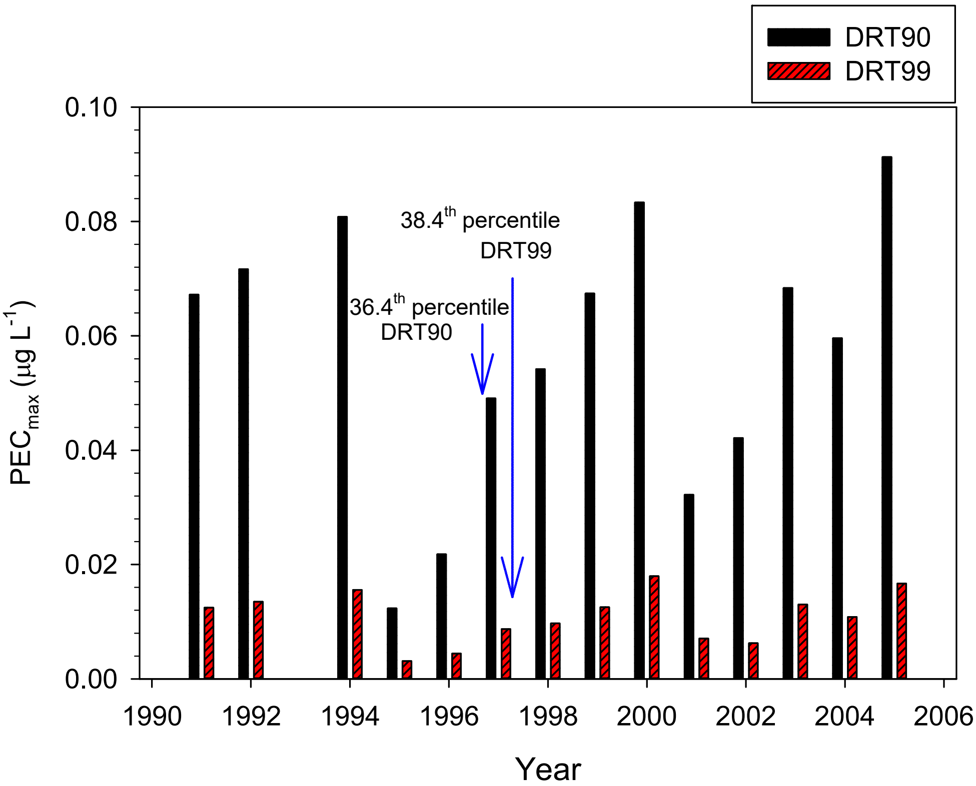

Figure 48 *Annual maximum concentration (dissolved) of substance I_p in the water of the 100 m target stretch for two classes of Drift Reducing Technology (DRT). The arrows indicate the 36.4th percentile annual maximum concentration for the DRT90 simulation and the 38.4th percentile annual maximum concentration for the DRT99 simulation.*

```
* Percentile summary for substance Ip
* --------------------------------------------------------------
* Rank  Percent     Yearly max.     Date of maximum
                    Concentration
                    dissolved
*  (-)       (%)      (µg.L-1)
* --------------------------------------------------------------
   1      3.33      0.3098E-04 1993-10-05-00h00    drainage
   2     10.00      0.1237E-01 1995-05-06-09h00    drift
   3     16.67      0.2181E-01 1996-05-13-09h00    drift
   4     23.33      0.3224E-01 2001-04-29-09h00    drift
   5     30.00      0.4215E-01 2002-04-29-09h00    drift
   6     36.67      0.4911E-01 1997-04-29-09h00    drift
   7     43.33      0.5421E-01 1998-05-06-09h00    drift
   8     50.00      0.5961E-01 2004-05-06-09h00    drift
   9     56.67      0.6724E-01 1991-05-13-09h00    drift
  10     63.33      0.6743E-01 1999-05-13-09h00    drift
  11     70.00      0.6838E-01 2003-04-29-09h00    drift
  12     76.67      0.7169E-01 1992-05-06-09h00    drift
  13     83.33      0.8085E-01 1994-05-06-09h00    drift
  14     90.00      0.8337E-01 2000-04-29-09h00    drift
  15     96.67      0.9131E-01 2005-04-29-09h00    drift
* The peak concentration (dissolved) in the water layer of Ip
* selected to represent the 36.40th percentile s 0.4911E-01 ug/L and is found
on 1997-04-29

* End of TOXSWA REPORT: Exposure concentration in water layer
```

Figure 49 *Information on the annual PEC_{max} concentrations in the target stretch of the ditch extracted from the *.sum output file of TOXSWA; simulation with substance I_p and* <u>*DRT90*</u>*. The last column is added manually and indicates the dominant source for the PEC_{max}.*

```
* Percentile summary for substance Ip
* --------------------------------------------------------------
* Rank  Percent     Yearly max.     Date of maximum
                    Concentration
                    dissolved
*  (-)       (%)      (µg.L-1)
* --------------------------------------------------------------
  1      3.33      0.5847E-05 1993-10-05-00h00   drainage
  2     10.00      0.3115E-02 1995-05-06-09h00   drift
  3     16.67      0.4445E-02 1996-05-13-09h00   drift
  4     23.33      0.6229E-02 2002-04-29-09h00   drift
  5     30.00      0.7063E-02 2001-04-29-09h00   drift
  6     36.67      0.8719E-02 1997-04-29-09h00   drift
  7     43.33      0.9716E-02 1998-05-06-09h00   drift
  8     50.00      0.1083E-01 2004-05-06-09h00   drift
  9     56.67      0.1247E-01 1991-05-13-09h00   drift
 10     63.33      0.1256E-01 1999-05-13-09h00   drift
 11     70.00      0.1301E-01 2003-04-29-09h00   drift
 12     76.67      0.1351E-01 1992-05-06-09h00   drift
 13     83.33      0.1555E-01 1994-05-06-09h00   drift
 14     90.00      0.1669E-01 2005-04-29-09h00   drift
 15     96.67      0.1799E-01 2000-04-29-09h00   drift

* The peak concentration (dissolved) in the water layer of Ip
*  selected to represent the 38.40th percentile is 0.8719E-02 ug/L and is
found on 1997-04-29

* End of TOXSWA REPORT: Exposure concentration in water layer
```

Figure 50 *Information on the annual PEC_{max} concentrations in the target stretch of the ditch extracted from the *.sum output file of TOXSWA; simulation with substance I_p and* <u>*DRT99*</u>*. The last column is added manually and indicates the dominant source for the PEC_{max}.*

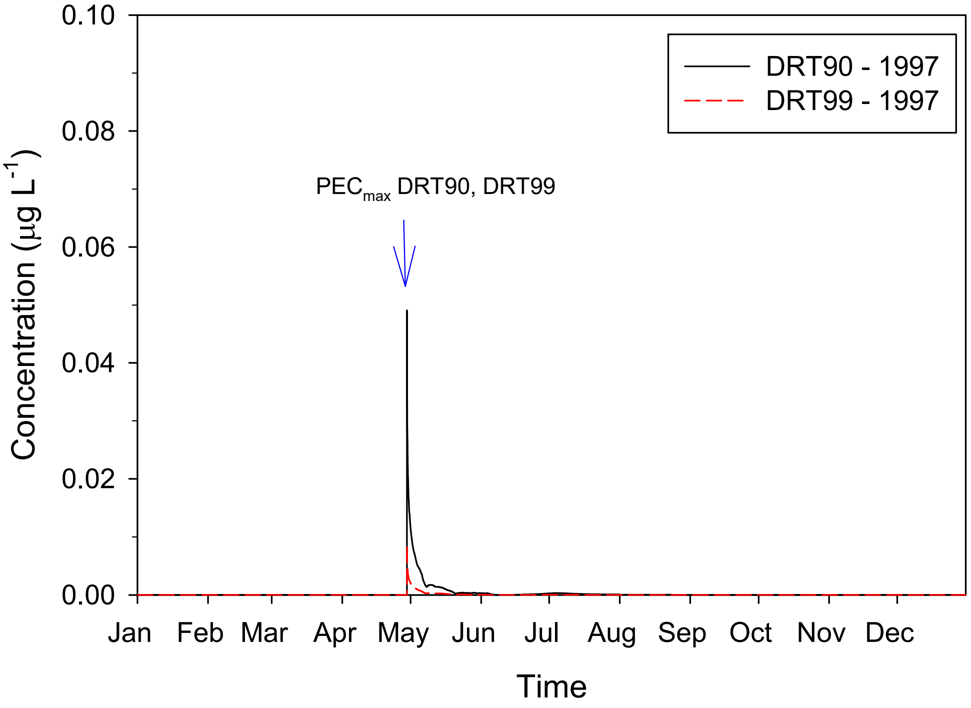

Figure 51 *Average concentration (dissolved) of substance I_p in the water of the 100 m target stretch as function of time for the year in which the target percentile is found (1997 for both DRT90 and DRT99).*

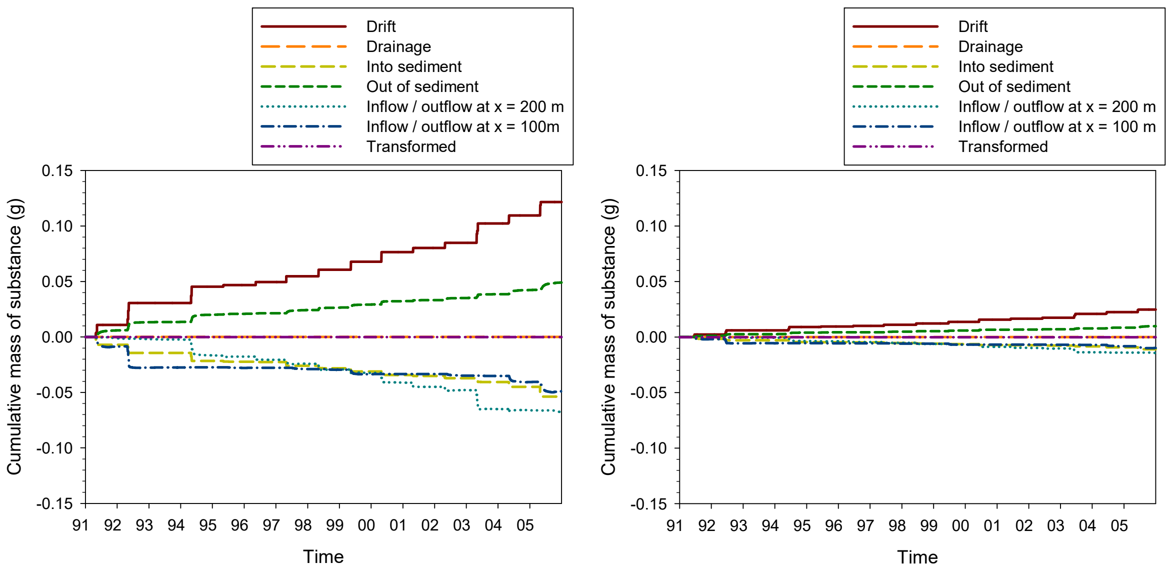

Figure 52 *Cumulative monthly mass balances of substance I_p for DRT90 (left hand side) and DRT99 (right hand side). Negative values indicate mass transport out of the water layer. Note, that due to varying flow directions substance may both enter the target stretch (inflow) or leave the target stretch (outflow) via the boundaries of the target stretch (x = 100m and x =200m).*

Figure 52 illustrates that in the water layer sorption to sediment and outflow out of the ditch dominate the fate of the I_p. After a spray drift event, I_p is quickly adsorbed to the sediment (mass balance term ' Into sediment'). However, once the water in the evaluation ditch is replenished with clean water (either from upstream or downstream depending on the flow direction), desorption occurs i.e. the substance is transferred back into the water layer of the ditch (mass balance term 'Out of sediment'). Transformation (DegT50 in water and sediment set to 1000d) and volatilisation play no role.

6.6.2 Additional analysis

Influence of the sediment properties on the annual PEC_{max}

The mass balances of Figure 52 showed that the dominant processes explaining the disappearance of substance I_p from the water layer are advection (transport with the water out of the ditch) and (diffusive) transport to sediment. In this section the influence of the sediment properties on the PEC_{max} is assessed by comparing the results of simulations with sediment properties taken from two different locations, i.e. Benschop and Willemstad.

As mentioned in the introduction section of this chapter, from four locations for which sediment properties were measured, two were selected as candidates for the scenario (i.e. location Benschop - high organic matter content and low bulk density and location Willemstad - lower organic matter content and relatively high bulk density, see Table 5 of this report).

Figure 53 plots for Benschop and Willemstad two types of concentration: i) the annual maximum concentration dissolved in the water layer and ii) the maximum total concentration in the water layer (i.e. dissolved + adsorbed to suspended solids). The Figure shows that there is hardly any difference between the annual maximum values of the total concentration in water simulated using the two different sediments. However, a difference is visible in the annual maximum values of the concentration dissolved in water.

In TOXSWA sorption to suspended solids is assumed to be an instantaneous process. Directly after a drift or drain pipe emission, the substance mass is partitioned between the water and the suspended solids, which causes therefore a decrease in the PEC_{max} (dissolved concentration). As the organic matter content of suspended solids is assumed to be equal to the organic matter content in the top 1 cm of the sediment, for strong adsorbing substances, the choice of the sediment indirectly has an influence on the PEC_{max} (dissolved concentration).

As the use of the Willemstad properties result in the highest PECsw values, it was decided to select the properties that give the highest PEC90 in the water layer for the scenario parameterisation, which are the properties of Willemstad. See also discussion in section 8.5.

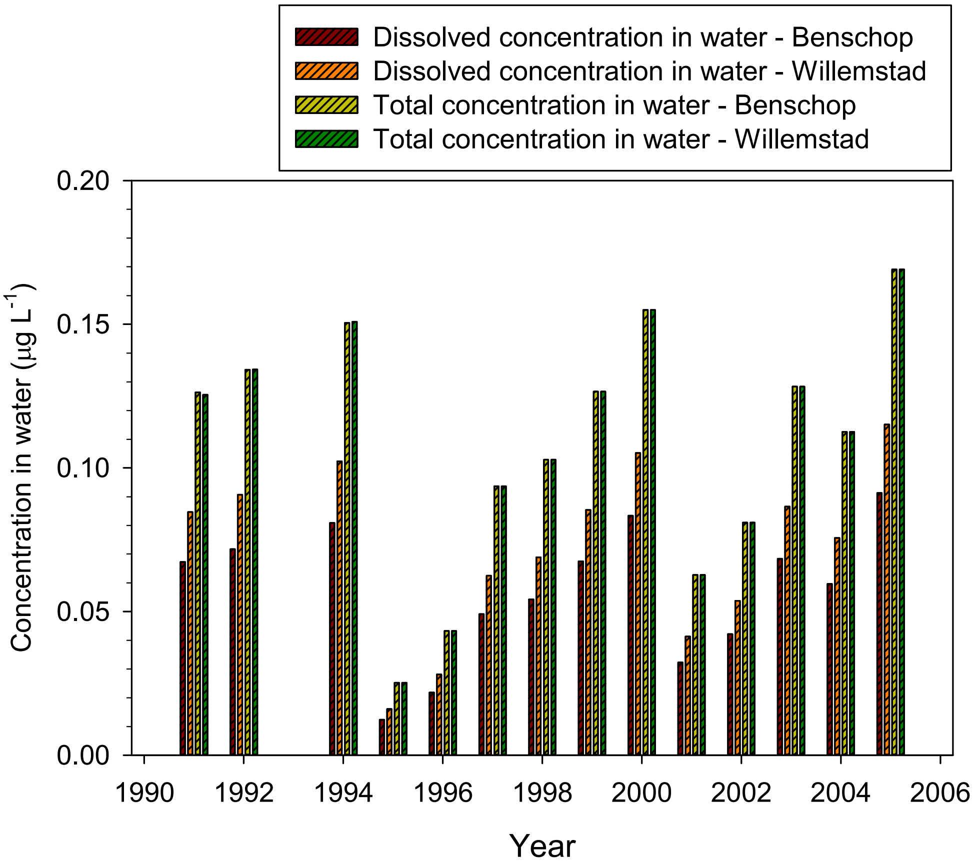

Figure 53 *Annual maximum concentrations (dissolved and total) of substance I_p, in the water of the 100 m target stretch for DRT90 using the sediment properties of the locations Benschop and Willemstad.*

Is accumulation of substance in the sediment an issue?
Another relevant question relating to the choice for the length of the warming-up period (5 years) is whether accumulation of substance in the sediment is an issue. At the start of the simulation substance is expected to accumulate in the sediment. Ideally within the warming-up period an equilibrium is reached, accumulation stops and the sediment delivers substance back to the water layer. The cumulative masses of the mass balance terms 'Into sediment' and 'Out of sediment' in Figure 52 seem to be mirrored for the period plotted (1991 – 2005; warming-up period not plotted), which suggests that an equilibrium is reached at the start of the evaluation period (1991).

Figure 54 shows the I_p total content in the sediment of the upper layer of the sediment for the two selected sediments and two target layers (0 – 1 cm and 0 – 5 cm). The plotted contents are averages over the 100 m target stretch of the scenario ditch. For both the top 1 cm and the top 5 cm the I_p contents are higher for the Benschop sediment than for the Willemstad sediment, which is explained by the higher organic matter content of the first sediment. All 4 lines shows peaks due to the spray drift events.

Related to the question whether a 5 year warming up period is sufficient, a gradual increase in content I_p in the top sediment layers is visible until 1993. After 1993 there seems to be a stabilisation of the content I_p in the top sediment layers. So, for this extremely strongly adsorbing compound approximately 7 years seem to be needed to reach a plateau content in the sediment. However, the Working Group agreed that a 5-year warming up period generally will be sufficient for the risk assessment.

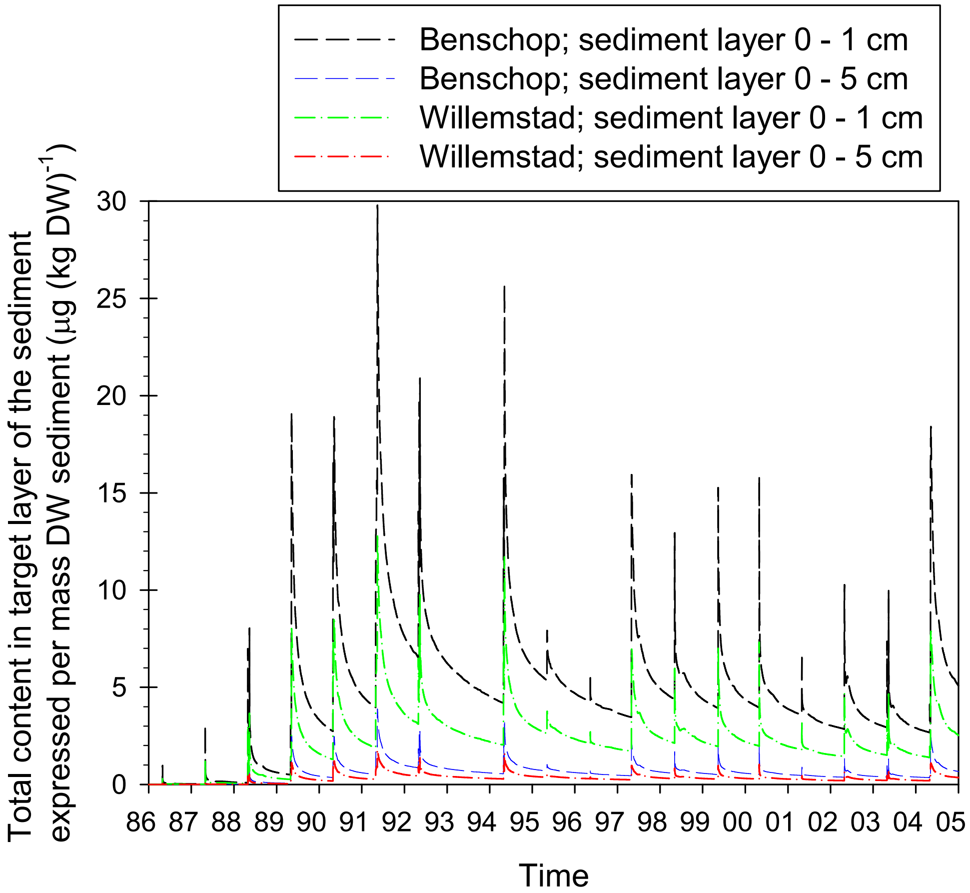

Figure 54 *Total content in the user-defined target layers of the sediment (0 – 1 cm and 0 – 5 cm); averaged over the target stretch of the water layer (x = 100 m to x = 200 m) and expressed per dry mass sediment. Results of simulations with sediment properties of the location i) Benschop and ii) Willemstad.*

6.7 Sensitivity to application time of the drainage emission scenario

While the drift deposition scenario shows a gradual course of depositions as a function of the application time (see Figure 18 in section 3.6), the sensitivity of the drain emission scenario to the application date is yet unknown. To test the sensitivity of the drain pipe scenario, simulations were made for a substance which is considered to be potentially sensitive to application timing. The substance is sprayed once per year via sideways and upward spraying with a dose of 1 kg ha^{-1}. In total 365 simulations were conducted (one for each day in a year). The spray drift contribution was considered to be negligible small (i.e. set to zero) and the temporal percentile (T90) is the T90 of the drainage emission scenario, i.e. the 63^{rd} percentile year for which the PEC_{max} is taken.

The selected substance is largely based on FOCUS-SW compound A (Table I.1, EFSA, 2020). It is a substance with a short half-life in soil ($DegT_{50}$ of 3 d) and a low sorption coefficient (K_{oc} of 10 L/kg) and thus susceptible to drainage and therefore very sensitive to the application timing. These type of substances are applied in fruit orchards but they are mostly sprayed downward (being a herbicide). As example substance it gives however insight in the variation that can be expected when the application date is changed. The same compound was used for a similar test by EFSA (2020). We refer to Annex 6 for details on the substance properties used in the simulations.

The 63^{rd} percentile PEC_{max} concentration for each application date is plotted in Figure 55. The calculated PEC_{max} varies per application date with a maximum difference of a factor 10. Specifically when the substance is applied in November the calculated PEC_{max} may vary considerable between two consecutive application dates. This implies that for situations in which the contribution of the drain pipe is dominant, the derived combined scenario may not give robust outcomes. This is undesirable for use in the regulatory context. However, given the event-driven nature of flow via macropores to drains, such a sensitivity to the application day is inherent and unavoidable. In Section 8.4 we will discuss how to use the developed scenario for situations in which the contribution of drain emission is dominant.

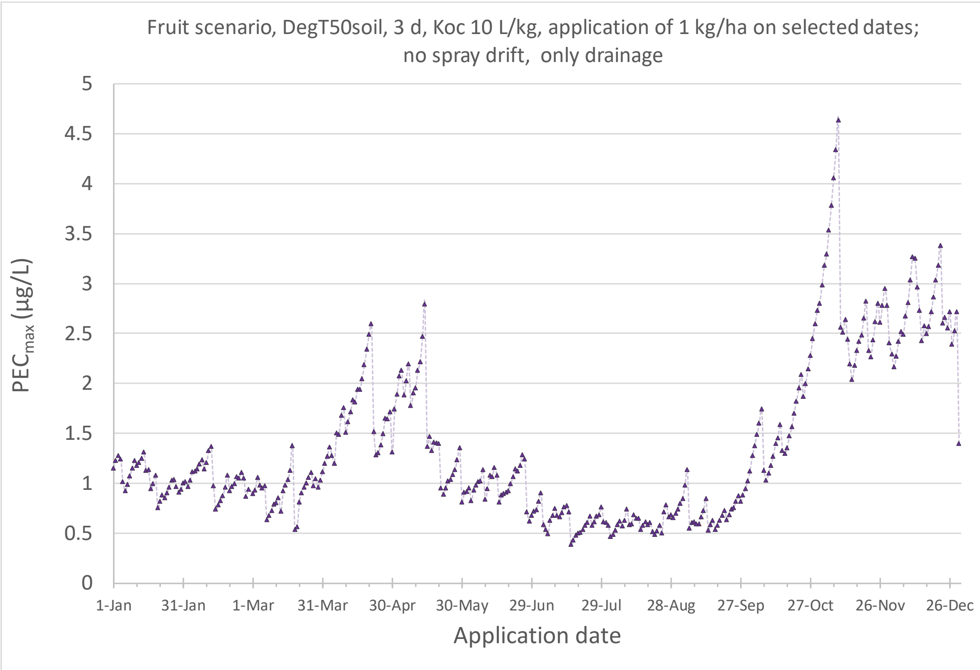

Figure 55 *PEC_{max} of the 63rd percentile year based on 365 simulations with substance A applied via spraying on all calendar days. The applied dose is 1 kg ha^{-1}.*

7 Atmospheric deposition

Analysis by Boesten et al. (2018) (see also Annex 1) showed that the contribution of atmospheric deposition is small except when high level of drift reducing techniques are used. Tiktak et al. (2012a) proposed for arable crops to use the first tier approach as developed by FOCUS (2008) for estimating the deposition due to volatilization after application to an adjacent field. The proposed methodology is simplified and conservative. The approach assumes that the wind blows perpendicular to the direction of the ditch, which is a worst-case assumption. Also, deposition values are based on data gathered in a wind tunnel which may lead to overestimation of the concentration in the air. Furthermore, atmospheric deposition is known to be strongly dependent on weather conditions, weather conditions are not considered in the methodology. Also, processes that affect volatilization from the plant surface are not considered and the impact of the formulation on the volatilization is not taken into account. In principle a higher tier could be developed since more national data is available. Such a methodology can build further on previous work on the exposure of residence and bystanders such as the Browse project (Browse, 2011-2013) and the OBO project (Gooijer et al., 2019).

Contrary to an earlier WG opinion not to include the atmospheric deposition entry route (Boesten et al, 2018), the WG now does propose to include this entry route. In this way the protectiveness of the scenario is maintained, although it is recognized that it may be very protective. Another drawback of including it is that the overall methodology is now somewhat unbalanced: a 'rough and conservative' atmospheric deposition entry route, combined with the sophisticated drift deposition and drainage entry routes. Nevertheless as a first estimate, and hence first tier, the approach as used by Tiktak et al. (2012a) and FOCUS (2008) will be applied. The contribution of atmospheric deposition will then be considered as additional to the drift deposition and the drainpipe contribution and will be added for each spray application independent of the weather conditions and timing.

Atmospheric deposition is considered to be relevant only for volatile substances, i.e. with a vapour pressure higher than 10^{-4} Pa when applied to the soil and for substances with a vapour pressure higher than 10^{-5} Pa when applied to the plant surface. The proposed deposits as percentage of the applied dose are given in Table 5. For substances with a very high vapour pressure, i.e. larger than 10^{-2} Pa, it is recommended to use expert knowledge. The atmospheric deposition is considered to take place in the 24 hours after a spray application. The FOCUS air deposition values for arable crops are used that are considered to deposit at a distance of 1 m from a wind tunnel. The values are multiplied by a factor 2 to account for the difference between atmospheric deposition from fruit orchards and arable crops. This is in line with recommendations in FOCUS (2008).

Note that atmospheric deposition is not part of the example calculations as the decision to add atmospheric deposition to the scenario was taken after the example calculations were done. At the same time the saturated vapour pressure for the example substances were below 10^{-5} Pa, so this would not have changed the results of the calculations.

Table 7 *Percentage of the dose that is considered to deposit on the ditch water surface in 24 hours after application. Values are based on the recommended values as provided in FOCUS (2008) and Tiktak et al. 2012a (for the last row).*

Range of vapour pressure	Application to the plant (fruit trees)	Application to bare soil[23]
VP < 10^{-5} Pa	0	0
10^{-5} Pa < VP < 10^{-4} Pa	0.18	0
10^{-4} Pa < VP <5 10^{-3} Pa	0.44	0.22
5 10^{-3} Pa < VP <10^{-2} Pa	3.12	1.56
10^{-2} Pa <VP	Expert judgement	Expert judgement

[23] Note that the application to bare soil is not relevant for fruit orchards. In case of treatment of the bare soil strips (downward spraying) these values are recommended to be used (not part of this report). Values are given here for completeness.

8 Discussion

8.1 Is the combined scenario protective?

Whether the approach of combining a 90th percentile based on spray drift and a 90th percentile based on drainpipe leaching would be appropriate for obtaining an overall 90th percentile is addressed in detail by Holterman et al. (2021). In general we may assume that, if one entry route is dominant, taking the 90th percentile of that route is appropriate. If both routes are almost equally important, the current procedure will lead to a higher overall percentile than the 90th percentile, which is conservative, as required in regulatory risk assessment.

8.2 Emission via surface overland flow

Surface overland flow, also referred to as runoff overland flow, can occur when the infiltration capacity of the soil is exceeded. Runoff overflow flow was not part of the emission routes considered in this report.

Surface overland flow mostly occurs in fine textured soils. When macropores are present, the excess water will be routed via the macropores towards the drain pipes. The macropore concepts that are used in the drain emission scenarios are described in Tiktak et al. (2012b). They consider macropores that penetrate partly towards the drainpipes leading to rapid drainage. And hence, this overland flow is included in the model and the scenario development.

Under wet conditions soils may be swollen such that the macropores are closed. In this case overland flow may be routed directly towards the surface water. The dynamic behavior of macropores is included in the macropore concepts used for the drain emission calculations. However, the overland runoff is not part of the emission routes towards the TOXSWA model. Given that (i) overland flow only occurs in specific situations, i.e. in case the moisture content is above a threshold value and that in all other situation the runoff water is routed towards the macropores, (ii) good agricultural practice should avoid overland flow, we consider the scenario presented to be sufficiently protective.

8.3 Crop-free buffer zone at the headland

In the simulation scenario, the optional crop-free buffer zone was added to each of the four sides of the orchard. Typically, the minimum crop-free buffer zone alongside the orchard is 3 m wide, while at the headland the minimum width is 6 m (The Environmental Activity Decree; MinI&W, 2021). It is however unlikely that a grower will add a 1-3 m crop-free buffer zone to the headland, as long as the headland is wider than the crop-free zone alongside. Therefore, reconsidering the approach that was followed in this report, a better approach would have been to use a 'smart' headland width, i.e. not to add a crop-free buffer zone to the headland unless the width of the total crop-free zone alongside the orchard tends to become wider than 6 m.

What would this 'smart' headland approach imply for the scenario development and their level of protection? It is expected that the overall protection of the drift deposition scenario is likely to be less than 90% countrywide, compared to 'smart' headland scenarios, i.e. since in the scenario as presented in this report a too wide headland is used, when a crop-free buffer zone is added, the *cfd* curves (like Figure 10) tend to slightly underestimate PEC values compared to a 'smart' headland approach. This leads to a temporal percentile T90 that is lower than that with 'smart' headlands. Consequently, overall protection is likely to be less than 90% countrywide, compared to 'smart' headland scenarios. Examples indicate that the current approach may lead to a PEC90 that is max.

12% too low, for a crop-free buffer zone of 3 m. For all other crop-free buffer zones the underestimation is less (Holterman et al., 2021). We consider this as acceptable.

8.4 Sensitivity to application time for drainage emission scenario

The drain emission scenario is found to be rather sensitive to the application date for a mobile and rapidly degrading substance (see section 6.7). This is undesirable as the outcome of the assessment is not robust and may lead to ambiguity in the calculation of the PEC90. In dialogue with the risk managers it was decided, as a first step, to define application schemes in the software (i.e. DRAINBOW) using BBCH crop stages, as such limiting the possibility to directly select a date. Practically this implies that an application scheme is defined based on crop development stages (BBCH) and that, based on a predefined relation between BBCH and calendar days, an application date is selected automatically by DRAINBOW for the assessment. The BBCH application window is laid down in the table of intended uses (GAP table) of the pesticide dossier. It is recommended to evaluate this approach and explore options to include the level of protectiveness of the selected dates in DRAINBOW.

The proposed approach corresponds to what is done in the 'repaired' EU FOCUS surface water scenarios (EFSA, 2020). Although the situation is quite different for the single Dutch fruit scenario and the 10 EU FOCUS scenarios their situation with respect to (i) robustness and (ii) protection level of calculated PECsw values (originating from drain inputs) is rather similar. This is further elaborated in Annex 9.

8.5 Sediment properties and how they affect the PEC90 in water and in sediment

Surface water
The example calculation for compound I_p, a pyrethroid, demonstrates that the total concentration in the water layer is more or less the same for the Willemstad sediment (12% organic matter in the 0-1 cm layer) and the Benschop sediment (22%). The type of concentration used in the aquatic risk assessment is however the dissolved concentration (PEC_{sw}). The Willemstad sediment has a lower organic matter content and gives higher PEC_{sw} than the Benschop sediment[24]. By using the Willemstad sediment the worst-case nature of the PEC_{sw} is secured. The Working Group proposes therefore to use the sediment properties of the location Willemstad for the scenario.

Note further that EFSA (2020, Annex N) demonstrated that the organic matter content in the sediment has virtually no influence on the PEC_{sw} for compounds with K_{oc} values of 10, 100 and 1000 L/kg and thus the worst-case nature of the PEC_{sw} is not affected by the organic matter content of the sediment for these compounds. This implies that the outcome of the assessment is not sensitive to the choice of the sediment type for these type of compounds.

Sediment
In the EU aquatic risk assessment the risks for sediment organisms and rooted water plants are assessed by using the exposure concentrations in the upper 1 or 5 cm, respectively of the sediment (EFSA, 2015). At EU level with its FOCUS scenarios, the sediment concentration (PEC_{sed}) values from the FOCUS surface water scenarios are used to evaluate the risks for sediment dwelling organisms and rooted water plants. Appendix N of EFSA (2020) demonstrated that the FOCUS sediment (having a relatively low organic carbon content of 5%) results in significantly lower PEC_{sed} values than a sediment with a higher organic carbon content. It concluded "that the FOCUS sediment with its 5% organic carbon content probably does not represent a 'realistic worst case' exposure in sediment in all

[24] This is mainly an indirect effect, i.e. the consequence of defining the organic matter content of the suspended solids in the water layer to be equal to the organic matter content of the upper 0-1 cm sediment layer.

the edge-of-field water bodies across the EU. In contrast, it neither represents a 'best case' exposure, because the FOCUS surface water scenarios intend to represent 'realistic worst case' exposure concentrations in surface water and the concentrations in the overlying water layer form one of the most important driving factors for the PEC_{sed}."

Given EFSA (2020), a similar rationale can be applied to the scenario presented in this report. The Willemstad sediment has the lowest organic matter content of the ditches sampled across The Netherlands of Adriaanse et al. (2015). Thus, the exposure concentration in the sediment, PEC_{sed}, calculated for the developed fruit tree surface water scenario of this report is not likely to represent a realistic worst-case exposure in sediment of ditches adjacent to fruit trees across The Netherlands. But neither it will represent a 'best case' exposure.

Therefore we judge that the calculated sediment concentration that corresponds to the PEC90 in surface water (which is provided by the scenario as presented in this report) is a reasonable estimate for the 90^{th} percentile sediment concentrations for sediment dwelling organisms and sediment rooted plants. The DRAINBOW instrument will therefore provide, next to water concentration, also concentrations in sediment in the upper 1 and 5 cm of the sediment.

8.6 Using the scenario for other type of crops than fruit trees

Upward and sideways spraying is, next to in pome and stone fruit orchards (large fruit), also common practice in small fruit orchards (e.g. red berry, blackberry), vineyards (grapes) and hop.

Small fruit orchards
Small fruit crops such as red and black currants, berries and grapes are sprayed regularly using sideways and upward spraying techniques (Van de Zande et al., 2011, 2019). However, compared to fruit trees the nozzle positions and air assistance of the application techniques are adapted to the specific crops and differ from those used in pome and stone fruit orchards. Until now no spray drift measurements have been conducted to quantify the spray drift deposition for these types of crops. In the current pesticide risk assessment procedures in the Netherlands small fruit crops are dealt with as large fruit crops for which only the full leaf stage drift curve is used (also for dormant stages of small fruit).

In this report we follow a probabilistic approach using multiple drift reduction curves and a spray drift model to calculate the drift deposition on the receiving water course. Given the complexity of the approach, a simple translation towards other crops cannot be made. On request of the risk managers, sideways and upward spray application on small fruit crops will be assessed with the fruit orchard scenario in which the fruit trees are considered to be in full leaf, which is in line with the current Dutch authorization procedure. The exact implementation is given in Annex 8.

Hop
Hop is grown in the Netherlands although to a limited extent. Van de Zande et al. (2019) considered the spray drift curves for hop and compared these to those of fruit trees and avenue trees and suggested to use the same drift curves as for fruit crops. We propose to use the relationship between development stage of hop and day-of-year though, by specifying the field period of the crop from emergence in April (week 13) to harvest, and taking the high hop plants down and from the field, in September/October (weeks 39/40)[25]. Currently, the pesticide risk assessment procedures in the Netherlands use for hop the spray drift curves for fruit trees in the dormant situation, this is considered protective. During the growing season of hop the spray drift deposition at surface water currently follows the large fruit drift curve and the calculated PEC values using the SPEXUS model could be as those presented in Figure 74 (Annex 8) for the period week 13-40.

[25] Practically this implies that for a specific development stage of hop a corresponding application date is selected. Then the drift deposition is calculated for this date according to the procedure as described in Chapter 3.

8.7 Metabolites

Metabolites can be formed in the soil, in the surface water and in the sediment. For metabolites formed in soil, the drainage emission will be the main emission route and hence the corresponding temporal percentile year should be selected, which is the 63rd percentile year. We propose to use the following approach in the exposure assessment of metabolites:

For all metabolites use the temporal percentile year as selected for the parent. For metabolites formed only in soil, use the 63rd percentile year. In case of metabolites formed both in soil as well as in water/sediment, the highest temporal percentile year (of drift and drainpipe) should be selected.

The developed scenario will become part of the software instrument DRAINBOW. This instrument supports the execution of exposure assessments for all types of combinations of substance properties and application schemes. Also, the formation of metabolites is simulated by DRAINBOW. The instrument provides maximum concentrations of the metabolites formed for all simulated years and standardly the metabolites concentration is selected in the final summary for the selected year based on the parent situation. Hence, the user can either use the selected year concentration or take one of the maximum concentrations in the list, which is also provided by DRAINBOW.

8.8 Other issues

Use of the scenario for the calculation of time weighted average (TWA) concentrations
The scenario selection procedure is based on the annual maximum concentration whereas the exposure assessment will also apply to e.g. annual or seasonal maxima of the 7-day time-weighted average (TWA) concentration. It is uncertain whether a selection procedure based on a TWA concentration would have given the same result. As long as drift deposition is the dominant entry route, it can be expected that there is a close relationship between a TWA peak concentration and an instantaneous peak concentration. For the drainage route the situation is less clear. This is general practice, also for example in EFSA (2020). It may be worthwhile to check the level of protection for situations in which the drain emission is dominant.

Predicted concentrations as part of the landscape
As described in Section 5.1, it is assumed that only the 100 m evaluation ditch is affected by the pesticides used in one single field of 1.4 ha. These numbers are based on a GIS analysis applied in the Rivierenland area (using the two different land use maps) of which a median size orchard field was selected (Wipfler et al. 2018).

At landscape level, there may be situations in which pesticide applications in other orchards outside the considered field may affect the concentration in the ditch and these orchards may be rather close (see e.g. Figure 56). This may potentially lead to higher concentrations in the evaluation ditch.

It may be worthwhile to explore the options for assessing exposure at a (interconnected) landscape level, also in view of possible effects of cumulation. This is however outside the scope of the work presented.

Figure 56 *Example of an area with fruit orchards as defined by the BRP map (black lines) and the LGN6 map (blue lines). Water area and water courses are indicated in red (source Wipfler et al., 2018).*

Extension of the derived temporal percentiles to allow different DRT classes in one scenario
With multiple applications and different application techniques, selecting the required temporal percentile is not straightforward. In the current procedure the conservative approach is followed by selecting the highest temporal percentile among the techniques used in the scenario (Section 3.5). It was estimated that this conservative approach could overestimate the overall 90th percentile PEC value by at most 6% (Holterman et al., 2021). In many cases this overestimation is likely to be much lower.

It is however unlikely that different DRT classes would be accepted in the authorisation procedure for inclusion on a plant protection product label since this leads to problems with law enforcement.

Assessment of the application rates
The exposure assessment procedure as developed in this report is based on application rates in terms of mass of active ingredient applied per surface area of the treated field (in kg/ha). The label of a product registered for application in Dutch fruit crops specifies for emulsifiable concentrate (EC) formulations the mass fraction (in %) or the volume fraction (in % or in mL/100 L) of the formulated product in the spray solution. For wettable powder formulations the label specifies the mass of formulated product to be applied in 100 L spray solution. Newer labels (from about 2015 onwards) specify additionally the maximum application rate in terms of mass of formulated product per surface area of treated field (kg/ha). The Ctgb bases the application rate used in the exposure assessment on the maximum application rate as specified on these newer labels. For the older labels the Ctgb calculates this application rate assuming that 1500 L spray solution is applied per hectare which is assumed to be the maximum volume of spray solution in practice (Ctgb, 2016). Often, the actual volume of spray solution is 150-300 L/ha for apples, pears and cherries and 200-500 L/ha for smaller fruit crops like berries.

It may happen in practice that a fruit grower sprays less than 1500 L/ha but applies nevertheless the maximum application rate (kg/ha) either based on the 1500 L/ha for the older labels or based on the maximum rate as specified on the label for the newer labels (personal communication H. Brouwer & C. van Griethuysen, 2016). For the exposure assessment as developed here this does not matter because this is based on the maximum application rate, irrespective of the volume of spray solution that is applied per hectare.

Already for many years it has been suggested to change the dose expressions on the label for fruit crops into a dose expression that is based on the area of the tree leaf canopy and the row spacing instead of the area of the treated field because the leafs are the target for the pest control (Toews et al., 2016). EPPO developed the Leaf Wall Area (LWA) parameter (see EPPO, 2021). The LWA is defined as the surface area of 'leaf wall' per surface area of treated field (m^2/ha). The LWA is commonly calculated as $LWA = 2\,h\,r$, where *h* is the height (m) of the treated canopy defined as the average distance from the highest leaf to the lowest leaf of a tree and where *r* (m/ha) is the total length of the tree rows per surface area of treated field. This *r* is calculated by dividing the surface area [m^2] per hectare of the treated field (i.e. 10 000 m^2/ha) by the distance [m] between the tree rows; so e.g. an interrow distance of 3 m gives *r* = 3333 m/ha. The factor 2 in the equation is needed because each tree has two sides.

The dose in this LWA-concept is defined as the mass of formulated product applied per surface area of treated field (so in kg/ha) for a reference LWA value of 10 000 m^2/ha (this corresponds to a canopy height h=1.5 m). The actual mass applied per surface area treated field is then proportional to the actual LWA. So in this concept the mass applied per surface area treated field is adapted to the distance between the rows and height of the leaf canopy. EPPO supports this trajectory and recommends to use this LWA-based dose approach for plant protection products in pome fruit, grapevine and high growing vegetables. This LWA-based dose approach has thus the large advantage that a lower dose can be used if the LWA is lower than the maximum value. See Van de Zande et al. (2019) for a more detailed discussion on the LWA-concept.

The maximum LWA in Dutch fruit crops is about 24.000 m^2/ha whereas a median LWA is likely to be about 12 000 m^2/ha. So, in principle switching to the LWA-based approach could lead to reduction of the total use of plant protection products in Dutch fruit crops by something like a factor 2. This would of course also decrease the total drift deposition onto the ditches by this factor. Therefore, we recommend to explore the possibilities for switching to LWA-based label instructions in Dutch fruit crops.

9 Conclusions and recommendations

9.1 Conclusions

This report describes a methodology for exposure assessment of aquatic organisms in watercourses after application of pesticides by sideways and upward spraying in Dutch fruit crops. The methodology results in a so-called 90th percentile exposure concentration (abbreviated PEC90). Three entry routes are considered to contribute to the exposure concentration, i.e. spray drift deposition, drainpipe emission and atmospheric deposition. Agronomical practices considered are based on Dutch apple and pear tree orchards. The methodology can be considered representative for all (high) orchard crops in the Netherlands. Furthermore the methodology applies for the drift-reducing techniques with a broad range of drift reduction classes. The methodology also applies for a crop-free buffer zones of which the widths range from 0 to 9 m.

The methodology was applied to three example assessments. The example calculations indicated that:

- When using drift reducing techniques up to the DRT90 class, drift is the dominant entry route as compared to emission via drains. When the drift is further reduced (DRT99 class) the contribution from drains may become dominant. Strongly adsorbing substances show a negligible impact of drainage.
- Drainpipe emissions vary per year and depend heavily on the weather conditions.
- The impact of the water depth dynamics in the evaluation ditch on the PEC90 is limited.
- Residence times in the evaluation ditch are short (the median residence time is 1 day). Accumulation of pesticide in the evaluation ditch is therefore limited. This is confirmed by the example assessments.
- For situations in which drift is strongly reduced and the contribution from drainpipe emission has become dominant, the PEC90 is sensitive to the application timing. In dialogue with the risk managers it was decided, as a first step, to define application schemes in the software (i.e. DRAINBOW) using BBCH crop stages, thus limiting the possibility to directly select a favourable date. This approach is in line with FOCUS surface water (EFSA, 2020).
- The spray drift deposits are strongly influenced by the leaf density. The change in crop canopy density throughout the year is reflected in the spray drift deposits and showed to be one of the important driving factors behind the variation in spray drift deposition over the year.
- Five years warming up period is sufficient to obtain an initial ‘plateau’ pesticide concentration in the sediment, accounting for pesticide mass accumulation, before further analysis can be done.

The calculated sediment concentration that corresponds to the PEC90 in surface water (which is provided by the scenario as presented in this report) is a reasonable estimate for the 90th percentile sediment concentrations for sediment dwelling organisms and sediment rooted plants.

The developed methodology can be used to assess the exposure concentration in hop and small fruit crops. An (available) specific relation between the crop development stage of hop and the day of the year can be used such that the correct day of the year is selected. For small fruit it was decided to use the drift deposition of large fruit crops in a full leaf situation only, which is in line with current Dutch authorization practice.

9.2 Recommendations

The main recommendations in this report are listed below.

For situations with low drift deposition the PEC90 is found to be sensitive to the application date. This is undesirable as the outcome of the assessment is not robust and may lead to ambiguity in the calculation of the PEC90, which is used in the risk assessment. In dialogue with the risk managers it was decided, as a first step, to define application schemes in the software (i.e. DRAINBOW) using BBCH crop stages, thus limiting the possibility to directly select a favorable date. It is recommended to evaluate this approach and explore options to include the level of protectiveness of the selected dates in DRAINBOW.

In addition to spray drift and drainage, atmospheric deposition has been included to guarantee protectiveness of the exposure scenario. For pragmatic reasons, the simple and conservative approach for arable crops is used, which is in line with current EU practices. In principle a higher tier could be developed since more national data is available. Such a methodology can build further on previous (national) work on the exposure of residence and bystanders.

We recommend to explore the possibilities for switching to LWA-based label instructions in Dutch fruit crops and which is reflected in the GAP (which is used for the risk assessment).

The current approach adopted for small fruit crops is to assume that the drift deposition is covered by the full leaf situation in large fruit crops. We recommend to underpin this assumption with targeted drift deposition measurements.

The contribution from drainpipe emission will be sensitive to the assumed direct deposition of pesticide on the bare soil and grass under and between the trees. Targeted measurements in fruit orchards can help to further underpin the deposition values used in the scenario.

The discretisation of the sediment layer in the ditch currently follows FOCUS Surface Water (Beltman et al., 2018). It would be good to better underpin this approach and assess the relation between the numerical error, the grid refinement and the run time of the model. Note that the numerical error is such that the water concentration is overpredicted and hence the provided concentrations are protective.

References

Adriaanse, P.I., S.J.H. Crum, J.A. Elbers, H.Th.L. Massop, W.H.J. Beltman, 2015. Sediment properties in five Dutch watercourses. Indicative measurements for registration procedure of plant protection products in The Netherlands. Alterra report 2574, Alterra, Wageningen, The Netherlands.

Bal J.J.M., Verhage, A.B., 2011. Water optimalisatie plan fruitteelt. ZLTO Advies 27-03-2012 – Kenmerk: ZJBA.2011.0888. Website: https://edepot.wur.nl/333091 (last entered 7 February 2020).

Beltman, W.H.J., M.M.S. ter Horst, P.I. Adriaanse, A. de Jong, 2018. Manual for FOCUS_TOXSWA v5.5.3 and for expert use of TOXSWA kernel v3.3; User's Guide version 5. The Statutory Research Tasks Unit for Nature & the Environment (WOT Natuur & Milieu). WOt-technical report 126.

BBCH, 2001. Growth stages of mono- and dicotylodonous plants, Version 2. Braunschweig, Federal Biological Research Centre for Agriculture and Forestry.

Boesten J.J.T.I, P.I. Adriaanse, M.M.S. ter Horst, A. Tiktak and A.M.A. van der Linden, 2015. Guidance proposal for using available DegT50 values for estimation of degradation rates of plant protection products in Dutch surface water and sediment. Wettelijke Onderzoekstaken Natuur en Milieu, Document 284.

Boesten J.J.T.I., 2017. Conceptual considerations on exposure assessment goals for aquatic pesticide risks at EU level. Pest Management Science, doi: 10.1002/ps.4701.

Boesten J.J.T.I., Holterman H.J., Wipfler L., ter Horst M.M.S., van de Zande J.C., Adriaanse P.I., 2018. Scenarios for exposure of aquatic organisms to plant protection products in the Netherlands. Part 2: Sideways and upward spraying in Dutch fruit crops (interim report). Wageningen, Wageningen Environmental Research, Report 2861.

Borren W., Hoogewoud J., 2014. Hercalibratie MORIA (in Dutch). Deltares report 1208395, Deltares, Utrecht.

Browse project (2011-2013); https://secure.fera.defra.gov.uk/browse/index.cfm). Date of access: 15 Febr.2021.

CBS; Centraal Bureau voor de Statistiek, 2021. *Fruitteelt; oppervlakte fruitboomgaarden, soort fruit.* http://statline.cbs.nl

Ctgb, 2016. Evaluation manual. Appendix C Spray volume list v2.0. https://english.ctgb.nl/documents/assessment-framework-ppp/2016/10/28/8.-appendices-spray-volume-list-v2.0-in-english-em2.1. Date of access: 15 Febr 2021.

EFSA. 2007. Opinion on a request from EFSA related to the default Q10 value used to describe the temperature effect on transformation rates of pesticides in soil. Scientific Opinion of the Panel on Plant Protection Products and their Residues (PPR-Panel). EFSA Journal 622: 1-32.

EFSA, 2010. Scientific opinion on the development of specific protection goal options for environmental risk assessment of pesticides, in particular in relation to the revision of the Guidance Documents on Aquatic and Terrestrial Ecotoxicology (SANCO/3268/2001 and SANCO/10329/2002). EFSA Journal 2010 8(10): 1821, 55 pp.

EFSA, 2013. Guidance on tiered risk assessment for plant protection products for aquatic organisms in edge-of-field surface waters. EFSA Journal 2013;11(7):3290, 186 pp. doi:10.2903/j.efsa.2013.3290.

EFSA, 2014. EFSA Guidance Document for evaluating laboratory and field dissipation studies to obtain DegT50 values of active substances of plant protection products and transformation products of these active substances in soil. EFSA Journal 2014;12(5):3662,37 pp., doi:10.2903/j.efsa.2014.3662.

EFSA PPR Panel (EFSA Panel on Plant Protection Products and their Residues), 2015. Scientific Opinion on the effect assessment for pesticides on sediment organisms in edge-of-field surface water. EFSA Journal 2015;13(7):4176, 145 pp. doi:10.2903/j.efsa.2015.4176

EFSA. 2017. EFSA Guidance Document for predicting environmental concentrations of active substances of plant protection products and transformation products of these active substances in soil. EFSA Journal 2017;15(10):4982. doi:10.2903/j.efsa.2017.4982

EFSA, 2020. Scientific report of EFSA on the 'repair action' of the FOCUS surface water scenarios. EFSA Journal 2020;18(6):6119, 301 pp. https://doi.org/10.2903/j.efsa.2020.

EPPO, 2021. Dose expression for plant protection products. European and Mediterranean Plant Protection Organisation, PP 1/239(3), Bulletin OEPP/EPPO (2021)0: 1-24 (https://pp1.eppo.int/standards/PP1-239-3)

FOCUS, 2000. FOCUS groundwater scenarios in the EU review of active substances. EC Document Reference SANCO/321/2000 rev2.

FOCUS, 2001. 'FOCUS Surface Water Scenarios in the EU Evaluation Process under 91/414/EEC'. Report of the FOCUS Working Group on Surface Water Scenarios, EC Document Reference SANCO/4802/2001-rev.2. 245 pp.

FOCUS, 2008. Pesticides in air: considerations for exposure assessment. Report of the FOCUS Working Group on Pesticides in Air, EC Document Reference SANCO/10553/2006 Rev 2 June 2008. 327 pp.

FOCUS, 2009. Assessing potential for movement of active substances and their metabolites to ground water in the EU. Report of the FOCUS Ground Water Work Group, EC Document Reference SANCO/13144/2010 version 1, 604 pp.

Gooijer, Y.M.; Hoftijser, G.W.; Lageschaar, L.C.C.; Oerlemans, A.; Scheepers, P.T.J.; Kivits, C.M.; Duyzer, J.; Gerritsen-Ebben, M.G.; Figueiredo, D.M.; Huss, A.; Krop, E.J.M.; Vermeulen, R.C.H.; Berg, van den F.; Holterman, H.J.; Jacobs, C.J.M.; Kruijne, R.; Mol, J.G.J.; Wenneker, M.; Zande, van de J.C.; Sauer, P.J.J., 2019. Research on exposure of residents to pesticides in the Netherlands: OBO flower bulbs (Onderzoek Bestrijdingsmiddelen en Omwonenden). http://library.wur.nl/WebQuery/wurpubs/549919.

Hazeu, G. W., Schuiling, C., van Dorland, G. J., Oldengarm, J., Gijsbertse, H. A., 2010, Landelijk Grondgebruiksbestand Nederland versie 6 (LGN6): vervaardiging, nauwkeurigheid en gebruik. Alterra-rapport; no. 2012

Holterman H.J., van de Zande J.C., Huijsmans J.F.M., Wenneker M., 2017. An empirical model based on phenological growth stage for predicting pesticide spray drift in pome fruit orchards. Biosystems Engineering 154, 46-61, dx.doi.org/10.1016/j.biosystemseng.2016.08.016.

Holterman H.J., van de Zande J.C., Huijsmans J.F.M., Wenneker M., 2018. Development of a spray drift model for spray applications in orchards. Wageningen Research. Report WPR-566, 72 pp. Doi: doi.org/10.18174/442091

Holterman H.J., van de Zande J.C., Wipfler E.L., Boesten J.J.T.I., Huijsmans J.F.M., 2021. Development of a probabilistic model for risk assessment of spray drift deposition onto surface waters for fruit orchards in the Netherlands. Wageningen Research. Report WPR-565 (in preparation).

ISO-22369, 2006. Crop protection equipment – Drift classification of spraying equipment. Part 1. Classes. International Organization for Standardization, Geneva.

Jacobs C.M.J. and van den Berg F., 2009. Assessment of atmospheric deposition onto surface waters. Presentation and extended abstract at Conference on Pesticide Behaviour in Soils, Water and Air, 14-16 September 2009, York, UK.

Kroon, T., Finke, P., Peereboom, I., Beuzen, A., 2001. Redesign STONE. De nieuwe schematisatie voor STONE: de ruimtelijke indeling en de toekenning van hydrologische en bodemchemische paramaters. Lelystad, RIZA, rapport 2001.017.

Leistra M., Smelt J.H., van den Berg F., 2005. Measured and computed volatilisation of the fungicide fenpropimorph from a sugar beet crop. Pest Manag Science 61: 151-158.

Leistra M, Smelt JH, Weststrate JH, van den Berg F, Aalderink R, 2006. Volatilisation of the pesticides chlorpyrifos and fenpropimorph from a potato crop. Environ. Sci. Technol. 40: 96-102.

Massop H.T.I., van der Gaast J.W.J., Hermans A.G.M., 2006. Kenmerken van het ontwateringsstelsel van Nederland. Alterra Report 1397, Alterra, Wageningen.

MinI&W (Ministry of Infrastructure and Water Management), 2021. Activiteitenbesluit Milieubeheer; valid since 1 January 2021; https://wetten.overheid.nl/BWBR0022762/2021-01-01 (in Dutch)

Scorza Júnior, R.P.; Smelt, J.H.; Boesten, J.J.T.I.; Hendriks, R.F.A.; van der Zee, S.E.A.T.M., 2004. Preferential flow of bromide, bentazon, and imidacloprid in a Dutch clay soil. Journal of Environmental Quality 33 (2004) 4.

Smit A.A.M.F.R., Siderius C., van Gerven L.P.A., 2009. Process description of SWQN, A simplified hydraulic model. Alterra Report 1226.1, Alterra, Wageningen.

Ter Horst, M.M.S., Wipfler, E.L., Boesten, J.J.T.I., H.Th.L. Massop, D.J.J. Walvoort, 2020. Ditch parameterisation, including the drainage route, for the aquatic exposure assessment of plant protection products in the Netherlands by sideways and upward spraying in fruit orchards. Wageningen, Wageningen Environmental Research, Report 3017.

TCT, 2017a. Beoordelingssystematiek emissiereducerende maatregelen open teelt. versie 15 december 2017. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

TCT, 2017b. Meetprotocol vaststellen driftreductie spuittechnieken [versie 1 juli 2017]. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

Tiktak A., Adriaanse P.I., Boesten J.J.T.I., van Griethuysen C., ter Horst M.M.S., Linders J.B.H.J., van der Linden A.M.A., van de Zande J.C., 2012a. Scenarios for exposure of aquatic organisms tot plant protection products in the Netherlands. Part 1: Field crops and downward spraying. RIVM Report 607407002/2012, RIVM, Bilthoven, The Netherlands, 129 pp.

Tiktak A., Boesten J.J.T.I., Hendriks R.F.A., van der Linden A.M.A., 2012b. Leaching of plant protection products to field ditches in the Netherlands. Development of a drainpipe scenario for arable land. RIVM Report 607407003/2012, RIVM, Bilthoven, The Netherlands, 106 pp.

Tiktak, A., A.M.A. van der Linden, J.J.T.I. Boesten, 2003. The GeoPEARL model. Model description, applications and manual. Bilthoven, RIVM, RIVM report 716601007/2003.

Toews R.B., Huby J.P., Pollmann B., Teichmann M., Schlotter P., Meier-Runge F., 2016. Dosiereinheiten in Raumkulturen - Notwendigkeit einer Harmonisierung aus der Sicht der Pflanzenschutzindustrie. 60. Deutsche Pflanzenschutztagung „Pflanzenschutz: Effizienz und Vielfalt' – 20. - 23. September 2016, Halle. Julius-Kühn-Archiv 454, 2016.265-268

Van den Berg F., ter Horst M.M.S., Beltman W.H.J., Adriaanse P.I., Boesten J.J.T.I., Groenwold J.G., Kruijne R., 2011. Assessment of pesticide exposure concentrations in a small catchment using the CASCADE-TOXSWA model. Presentation and extended abstract at XIII Symposium Pesticide Chemistry - Environmental Fate and Ecological Effects, Piacenza, Italy.

Van den Berg, F., A. Tiktak, J.J.T.I. Boesten & A.M.A. van der Linden, 2016. PEARL model for pesticide behaviour and emissions in soil-plant systems; Description of processes. The Statutory Research Tasks Unit for Nature & the Environment (WOT Natuur & Milieu). WOt-technical report 61. 134 blz.; 19 Figs; 1 Tab.; 105 Refs; 4 Annexes.

Van den Berg F, Tiktak A, Hoogland T, Poot A, Boesten JJTI, van der Linden AMA and Pol JW, 2017. An improved soil organic matter map for GeoPEARL_NL; Model description of version 4.4.4 and consequences for the Dutch decision tree on leaching to groundwater. Wageningen Environmental Research report, Report 2816.

Van de Zande JC, Wenneker M, De Bruine A, 2011. Inventarisatie kleinfruitteelten en afleiden driftdepositie en maatregelpakketten. Wageningen UR Plant Research International, Plant Research International, Rapport 398. Wageningen.2011. 32p.

Van de Zande J.C., Holterman H.J., Huijsmans J.F.M., 2012. Spray drift for assessment of exposure of aquatic organisms to plant protection products in the Netherlands. Part 1: Field crops and downward spraying. Report 419, Plant Research International, Wageningen, 84 pp.

Van de Zande J.C., Holterman H.J., Huijsmans J.F.M., Wenneker M., 2019. Spray drift for assessment of exposure of aquatic organisms to plant protection products in the Netherlands. Part 2: Sideways and upward sprayed fruit and tree crops. Wageningen Research, Report WPR-564, 74 pp. Doi: doi.org/10.18174/448381

Van de Zande, J. C., & ter Horst, M. M. S. (2019). Crop related aspects of crop canopy spray interception and spray drift from downward directed spray applications in field crops. Wageningen Research, Report WPR-420. https://doi.org/10.18174/514310

Wipfler, L., ter Horst, M., Massop, H., Walvoort, D., 2018. Ditch parameterisation for the aquatic exposure assessment of plant protection products in the Netherlands by sideways and upward spraying in fruit orchards. Wageningen Environmental Research rapport; No. 2850.

Abbreviations

BBCH-scales	Phenological development stages of crops. BBCH stand for the stakeholders involved: Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie
bas-DRT-w combination	Combination of basic application scheme, DRT class and width of the crop-free buffer zone
cfd	Cumulative frequency distribution
cfbz	Crop-free buffer zone; optional zone to add to the minimal agronomic crop-free zone to decrease spray drift deposits on the edge-of-field ditch
cpdf	Cumulative probability density function
d-fi scenario	Aquatic exposure scenario for downward spraying in field crops
DRT	Drift-reducing technology
ERC	Ecotoxicologically Relevant type of Concentration
LWA	Leaf Wall Area
PEC90	90^{th} percentile exposure concentration, concentration that corresponds to the overall 90^{th} percentile of exposure concentrations
PEC_{max}	Annual maximum Predicted Environmental Concentration
proSPEXUS	Probabilistic SPEXUS model for countrywide risk assessment
SPEXUS	Spray drift exposure model for upward and sideways applications (for one orchard, one ditch)
SPSU	Spatial population of spatial units
STPC	Spatio-temporal population of concentrations
SU	Spatial unit
su-fr scenario	Aquatic exposure scenario for sideways and upward spraying in fruit crops
tcfz	Total crop-free zone. The total crop-free zone is considered to be the sum of the minimal agronomic crop-free zone and the crop-free buffer zone.
TPC	Temporal population of concentrations
T90	Local temporal percentile that corresponds to the 90^{th} overall percentile (of exposure concentrations)
TWA	Time-weighted average
xSPEXUS	Extended SPEXUS model; specifically adapted for use in DRAINBOW

Annex 1 Possible contribution of atmospheric deposition

This text is a copy of Chapter 6 in Boesten et al. (2018).

Tiktak et al. (2012a) included atmospheric deposition in the *d-fi* scenario by using conservative default values for this deposition based on the vapour pressure of the substance as recommended by FOCUS (2008). Their Table 13 and Figure 38 indicate that this results in a deposition of about 0.2% of the dose if the vapour pressure of the substance exceeds 10^{-4} Pa (this 0.2% is introduced into TOXSWA as a constant rate over the first 24 h after application). Figure 57 indicates that about 40% of the pesticides have a vapour pressure higher than 10^{-4} Pa. The spray drift deposition for DRT99 and a crop-free buffer zone of 9 m may become as low as about 0.02-0.03%. So using the conservative default values from FOCUS (2009) in combination with our sophisticated spray drift approach seems inappropriate. However, it seems necessary to gain more insight into more realistic estimates of the contribution of atmospheric deposition.

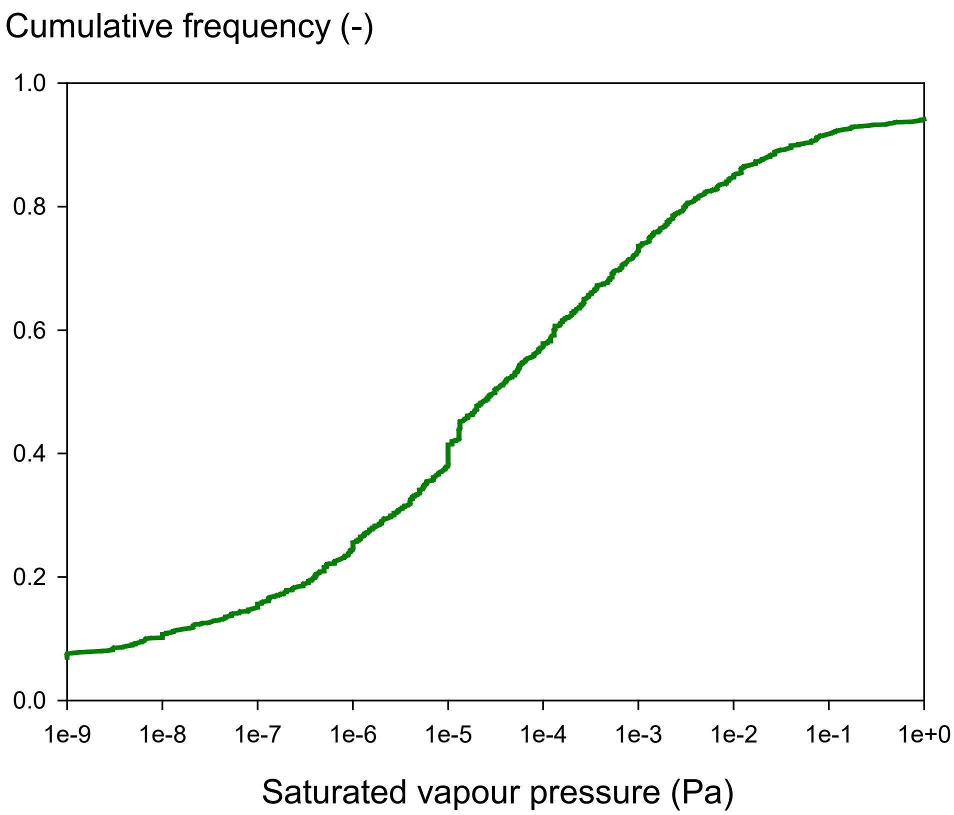

Figure 57 *Cumulative frequency of saturated vapour pressures of pesticides taken from the FOOTPRINT database (version of 29 May 2015).*

Within the scope of a Water Framework Directive project on the quality of surface water at the catchment scale, Jacobs and Van den Berg (2009) and Van den Berg et al. (2011) presented the results of calculations of atmospheric deposition of a plant protection product with the coupled PEARL-OPS model onto a network of Dutch ditches in the Klazienaveen-Zwartemeer catchment (total surface of the area is about 10 km^2) after spray applications to the plant surface of sugar beets in the catchment. These calculations were intended to demonstrate the possibilities of the coupled PEARL-OPS model (F van den Berg and CMJ Jacobs, personal communication, 2017). In these sample calculations they assumed an application of 1 kg/ha of fenpropimorph on 1, 2, 3, 4, 5, 6, 7, 8, 9 and

10 May 2003 onto one of ten fields within this area, in a randomly selected order. The surface area of the sugar beet fields ranged from about 2 to 30 ha (Figure 58). The saturated vapour pressure of fenpropimorph was assumed to be 2.2 mPa and its water solubility 4.3 mg/L (both at 20ºC). The logarithm of its K_{om} was 3.13. Penetration into the leaf tissue and photo-transformation on the leaf surface were taken into account using first-order kinetics, with half-lives of 0.66 and 0.433 d, respectively. The atmospheric deposition was characterised by the cumulative mass deposited per surface area of ditch over the first 14 days of May. Meteo data were taken from meteorological station 'De Bilt' in the centre of the Netherlands. The wind direction at this meteorological station varied between 1 and 14 May 2003 between south west and north east. To the best of our knowledge, these are the only simulations available of atmospheric deposition of pesticides in the Netherlands using sophisticated models such as PEARL and OPS. Therefore, these simulations are quite valuable for the assessment of the potential significance of atmospheric deposition of pesticides onto Dutch ditches.

The PEARL simulations were carried out with an option that not only considers volatilisation as a dissipation process on plant leaves, but also the competing processes penetration into the plant tissue and photo-transformation on the plant leaves. This resulted in an average of 25% volatilisation of each dose within a few days (ranging between 19 and 33%, depending on the day of application). In field experiments in the Netherlands Leistra et al. (2005, 2006) found 12% volatilisation of fenpropimorph after application to sugar beets and 7% volatilisation after application to potatoes. So, let us assume that a 10% cumulative volatilisation of fenpropimorph from plant surfaces is realistic for Dutch conditions. This means that the simulated depositions onto the ditches may need to be divided by a factor of 2.5 to obtain realistic values.

Figure 59 shows that the simulated cumulative deposition is less than 1 g/ha for about 30% of the ditches, about 1-3 g/ha for about 35% of the ditches, about 6 g/ha for 20% of the ditches and about 10-20 g/ha for about 15% of the ditches. So a 90th spatial percentile in this landscape geometry would be in the order of 10 g/ha which corresponds with 1% of the dose of 1 kg/ha. Keeping in mind that we have to divide by a factor of 2.5, we get 0.4% deposition. This is close to the default deposition of 0.22% as recommended by FOCUS (2008) for substances with a saturated vapour pressure above 10^{-4} Pa, as shown in Table 13 of Tiktak et al. (2012a). So these simulations confirm that a deposition of a few tenths of percent of the dose may occur. This is in the same order of magnitude as the spray drift deposition for DRT99 (Figure 18). So these results indicate that atmospheric deposition cannot be ignored in this exposure assessment of aquatic organisms after spray applications in Dutch fruit crops. We recommend therefore to develop realistic exposure scenarios for atmospheric deposition. However, it is foreseeable that this will require considerable multi-year research efforts given the required complexity to obtain 90th percentiles of the atmospheric deposition rates for applications in Dutch fruit crops.

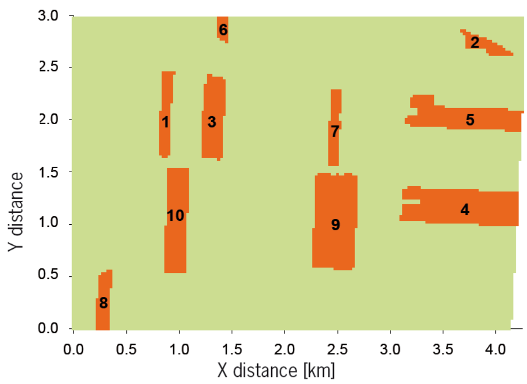

Figure 58 *Location and size of the treated sugar beet fields. The Y axis is in the direction from south to north. The number of each field indicated the day number in May 2003 in which the field was sprayed with fenpropimorph at a rate of 1 kg/ha (so 1 means application on 1 May).*

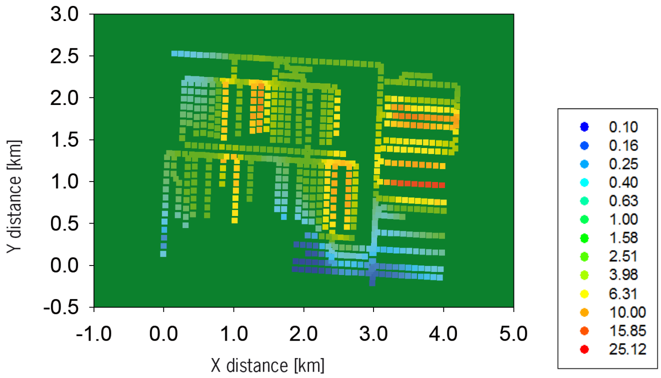

Figure 59 *Cumulative mass deposited per surface area of ditch between 1 and 10 May 2003. The numbers are in g/ha.*

References

FOCUS, 2008. Pesticides in air: considerations for exposure assessment. Report of the FOCUS Working Group on Pesticides in Air, EC Document Reference SANCO/10553/2006 Rev 2 June 2008. 327 pp.

Jacobs CMJ and van den Berg F, 2009. Assessment of atmospheric deposition onto surface waters. Presentation and extended abstract at Conference on Pesticide Behaviour in Soils, Water and Air, 14-16 September 2009, York, UK.

Leistra M, Smelt JH, van den Berg F, 2005. Measured and computed volatilisation of the fungicide fenpropimorph from a sugar beet crop. Pest Manag Science 61: 151-158.

Leistra M, Smelt JH, Weststrate JH, van den Berg F, Aalderink R, 2006. Volatilisation of the pesticides chlorpyrifos and fenpropimorph from a potato crop. Environ. Sci. Technol. 40: 96-102.

Van den Berg F, Ter Horst MMS, Beltman WHJ, Adriaanse PI, Boesten JJTI, Groenwold JG, Kruijne R, 2011. Assessment of pesticide exposure concentrations in a small catchment using the CASCADE-TOXSWA model. Presentation and extended abstract at XIII Symposium Pesticide Chemistry - Environmental Fate and Ecological Effects, Piacenza, Italy.

Annex 2 Background information for the protocol for determining temporal percentile of both drift and drainage

The protocol for deriving the temporal percentile year in case of a combined scenario of drift deposition and drainpipe emission is given in Section 4.3. This annex gives more information on how to derive the PEC_{drift} and the PEC_{drain}.

Deriving PEC for spray drift entry

Suppose drift enters at t=0, with mass m_{drift} = B·A (mg), where B (mg m^{-2}) equals the applied dose times the drift percentage and A (m^2) is the surface area of the ditch. Assume the pesticide mixes perfectly and instantly with the water in the ditch, leading to a concentration of:

$$C_0 = \frac{m_{drift}}{V_0} = \frac{B \cdot A}{V_0} \qquad (2)$$

where V_0 is the water volume (m^3) at the considered time of application. Assume water flowing in from upstream does not contain pesticides. The average flow velocity in the ditch is v (m h^{-1}). This implies that both inflow and outflow is given by Q_{flow} = v·S where S is the cross-section of the ditch (approximately surface width times water depth). Then, if no other sources are present, the concentration (PEC_{drift}) will decrease exponentially, with a characteristic time τ = Q_{flow}/V_0 (h):

$$PEC_{drift} = C_0\, e^{-\frac{t}{\tau}} \qquad (3)$$

Example: assume a 100m ditch, width 1m, depth 0.3m (V_0=30 m^3, S=0.3 m^2), flow velocity v = 10 m h^{-1}. Then Q_{flow} = 3 m^3 h^{-1} and τ = 10 h. Say spray drift deposits are 1% of the applied dose and the applied dose is 1 kg/ha = 100 mg/m2. Then the mass entering the ditch by drift deposits is 100 mg. The PEC due to drift deposition is shown in Figure 60. Clearly, the PEC_{max} occurs at t=0 and equals m_{drift}/V_0 = 100mg/30m^3 = 3.3 mg m^{-3}. So the contribution of drift to PEC_{max} to account for is C_0 as given by Eq.(2).

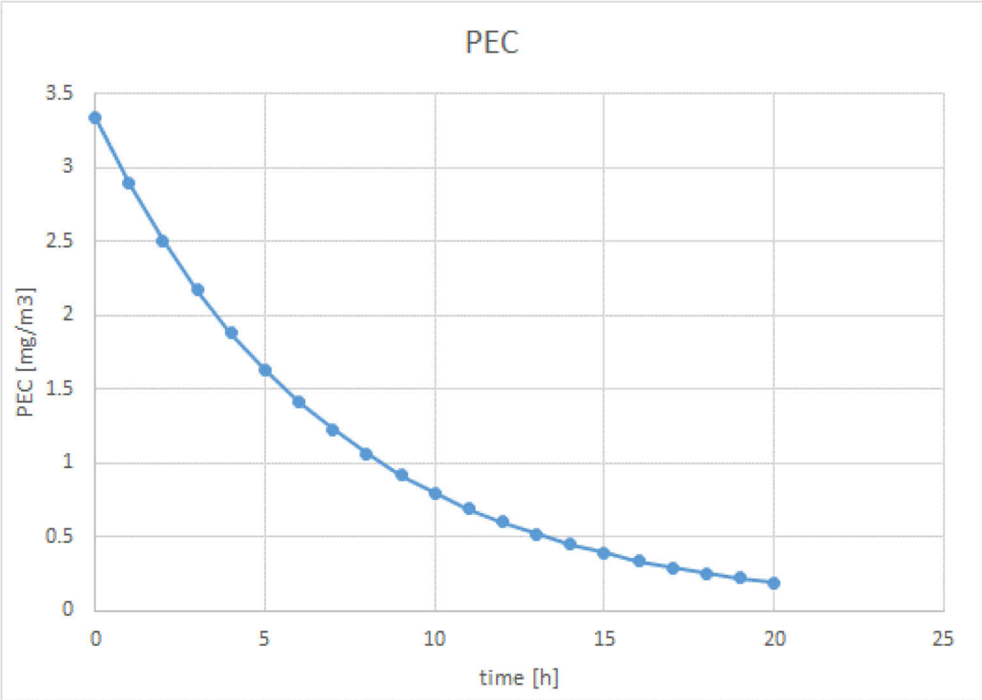

Figure 60 *Example of PEC with time, due to drift input at t=0 as calculated while using Eq. (2) and (3) for the example case as described in the text; no other sources present.*

When the waterflow through the segment changes on an hourly base, then τ changes and each hour the concentration due to drift input is reduced to a factor $e^{-\Delta t/\tau(t)}$ of the concentration at the start of that hour. Thus, Eq.(3) could be replaced by the following product:

$$PEC_{drift}(n\,\Delta t) = C_0\ \prod_{i=1}^{n} e^{-\frac{\Delta t}{\tau_i}} \tag{4}$$

This equation gives the remaining drift portion of the pesticide concentration after n hours (assuming as before, Δt=1h); where τ_i is the characteristic time during the i-th hour. In the calculation of the PEC_{drift} as part of the protocol it is assumed that PEC_{drift} is equal to C_0, i.e. PEC_{drift} is calculated with Eq (2).

Deriving PEC for drainage entry

Let's assume that drainage input is constant with time, with water inflow Q_{drn} ($m^3\ h^{-1}$) and pesticide concentration C_{drn} (mg m^{-3}). Then each hour the mass of pesticide entering the ditch equals $Q_{drn}\cdot C_{drn}\cdot \Delta t$ (mg) (where Δt=1h). Assume, like above, this mass mixes perfectly and instantly with the water in the ditch. Apart from mass of pesticide, also water enters the ditch, at flow rate Q_{drn}. Assume further that the changes in the water level during the timestep are very small and hence the water volume V (m^3) of the ditch can be considered as constant. Consequently, the flow rate downstream equals the total inflowing water, i.e. $Q_{flow}+Q_{drn}$. The corresponding characteristic time is $\tau_{tot} = V/(Q_{flow}+Q_{drn})$ (h). Assuming that no other sources are present, the concentration is described by:

$$PEC_{drain} = C_e\left(1 - e^{-\frac{t}{\tau_{tot}}}\right) \tag{5}$$

Where C_e is the equilibrium concentration, given by

$$C_e = C_{drn}\ \frac{Q_{drn}}{Q_{flow}+Q_{drn}} \tag{6}$$

Example: assume C_{drn} = 1 mg m^{-3} (=1 μg L^{-1}) and Q_{drn} = 1 $m^3\ h^{-1}$, and the same ditch and flow velocity conditions hold as with the example for spray drift. Then τ_{tot} = 7.5 h and C_e = 0.25 mg m^{-3}. PEC increases exponentially, as in Figure 61. The PEC_{max} occurs after some time when the inflow of pesticide mass from the drains equals the outflow of pesticide mass, typically after time $3 \cdot \tau_{tot}$ (h), provided all conditions remain constant long enough. This PEC_{max} equals C_e given above.

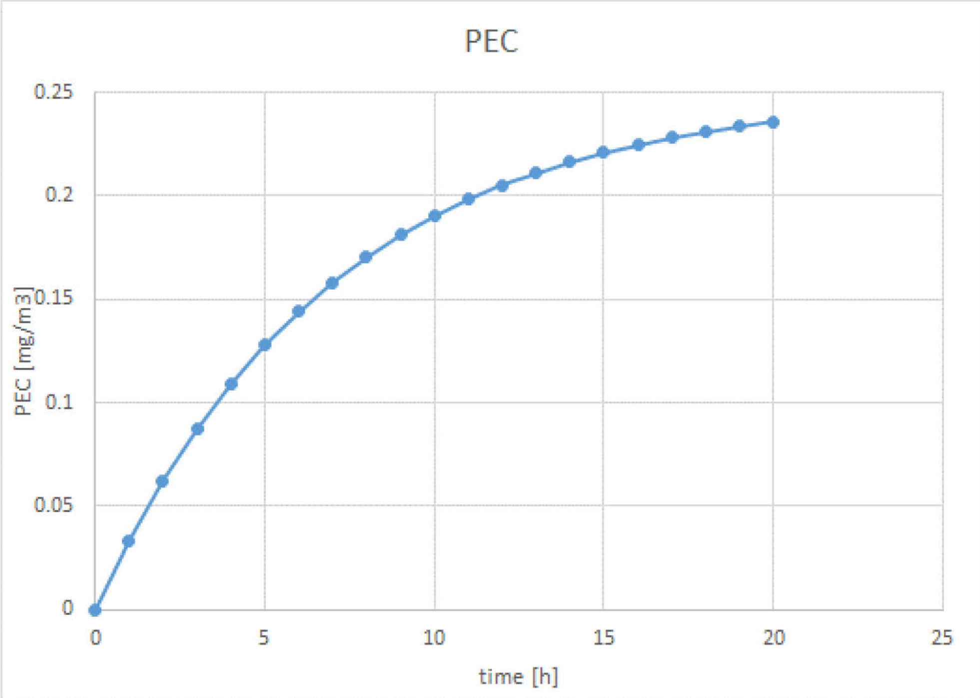

Figure 61 *Example of calculated concentrations with time, due to constant drain input starting at t=0 calculated with Eqs.(5) and (6); no other sources present.*

In reality, drain input will not be constant for such a long time. Probably, both Q_{drn} and C_{drn} change with time. To compute the contribution from drainage, Eqs.(5) and (6) could be applied for each hour of one day. In many cases, however, τ_{tot} will be much larger than 1h, so the C_e of that specific hour will not be reached within 1h. Besides, although C_e may change each hour, there will be a cumulating effect of drain inputs during subsequent hours. This means that the PEC from drainage may approach a kind of 'mean' value of all C_e values occurring. Therefore, taking the average value of C_e probably is a reasonable estimate of the contribution of drainage to the maximum PEC during one day:

$$PEC_{drain} = \frac{1}{24}\sum_{t=0}^{23} C_e(t) \qquad (7)$$

Where $C_e(t)$ is computed for each hour, using Eq.(6), considering all factors (C_{drn}, Q_{drn}, Q_{flow}) at time t. this gives:

$$PEC_{drain} = \frac{1}{24}\sum_{t=0}^{23} \frac{C_{drn}(t)Q_{drn}(t)}{Q_{flow}(t)+Q_{drn}(t)} \qquad (8)$$

Note that this estimate of PEC_{drain} usually is smaller than the average of the hourly $C_{drn}(t)$ values, as $C_e \leq C_{drn}$ according to Eq.(6).

Note further that as the characteristic time τ_{tot} usually will be (much) larger than 1 h[26], it is unlikely that the actual PEC in the ditch will reach this maximum (or minimum) value of C_e i.e. the real concentration may lag behind these concentrations. Despite this possible lag in the prediction of the PEC due to drain emission, for selecting a proper temporal percentile year, Eq (8) will be a sufficient adequate estimate (fit for purpose).

[26] Ter Horst et al. (2020), their Annex 7 provides residence times. The median annual residence time is between 6-26 hr, the 90th percentile is between 30-458 hr.

Multiple spray applications in one year

Does the protocol hold when multiple spray applications take place within one year? So far, the PEC_{max} for each year was evaluated for the risk assessment. Obviously there can only be one PEC_{max} each year, so with multiple spray applications, only one of these applications is responsible for the PEC_{max}. On the other spraying dates the peak PEC must be less than the annual maximum: $PEC \leq PEC_{max}$. Therefore, on the day at which PEC_{max} occurs, the above protocol can be applied.

Other processes

So far, only inflow (from drains and from the upstream segment) and outflow (into the downstream segment) were considered. Other exchange processes (e.g. with sediment, degradation) were disregarded. Such processes would act on pesticides originating from spray drift and drains in an equal way, so the ratios of pesticide fraction from the drift and drainage entry routes would not change.

Annex 3 Sensitivity of drift scenario to temporal percentile

In this annex the sensitivity is assessed of the drift scenario to the temporal percentile used. This assessment was done to better understand the impact of using a temporal percentile that is lower or higher than the selected percentile.

The temporal percentiles for scenarios with spray drift only are shown in Figure 62 for all basic scenarios (including different application techniques and crop-free buffer zones). The graph shows that in many cases the temporal percentile for spray drift is below that for drainage (63%). In some cases, mainly the L1 and E1 scenarios, the temporal percentile for spray drift is above 63%, Several examples will be worked out to investigate the combined effect of drift and drainage on protection levels.

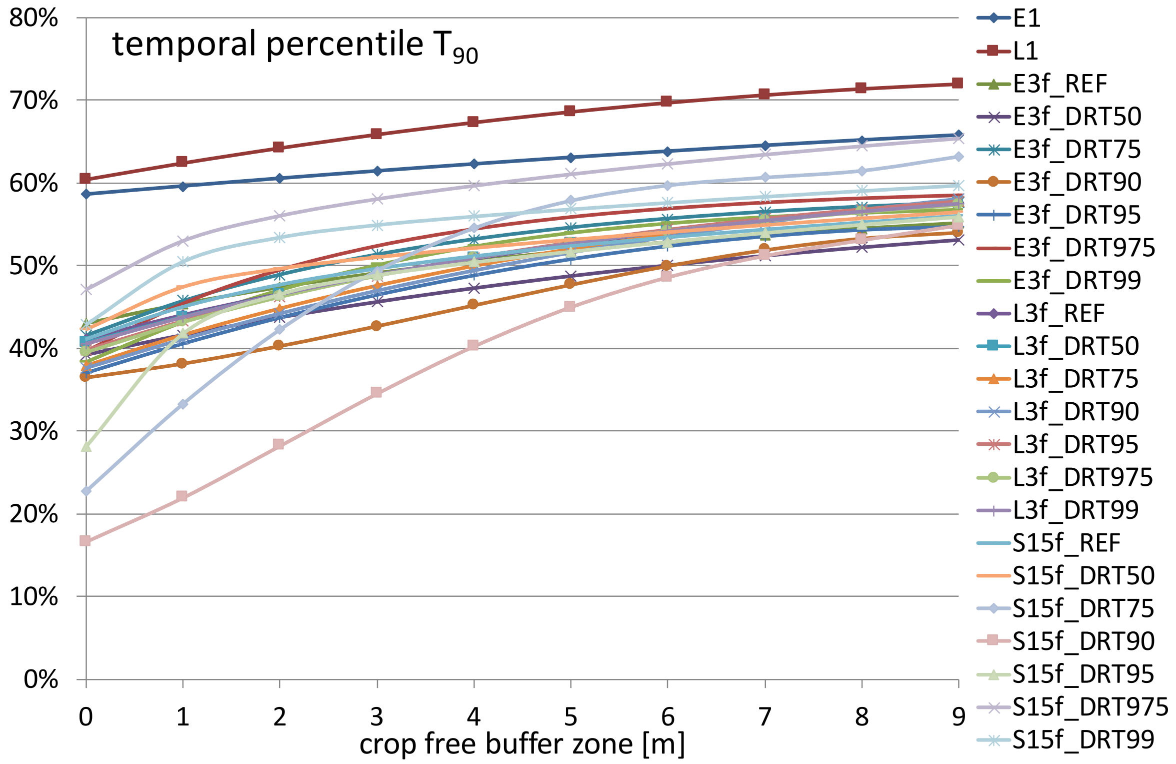

Figure 62 *Temporal percentiles for scenarios with drift as the only entry route, as a function of crop-free buffer zone; for different basic scenarios and application techniques. For E1 and L1 the differences in temporal percentile between different application techniques is negligible. Therefore only one curve suffices for the E1 scenarios and L1 scenarios.*

Example 1 - scenario E1

For basic scenario E1 (a single 'early' application in a dormant orchard), using a conventional application technique[27] without additional crop-free buffer zone, the countrywide 90th percentile pesticide concentration (PEC90) is 82 mg/m^3 (assuming an applied dose rate of 1 kg/ha). For the selected watercourse the required temporal percentile is 58%. This is schematically derived following the red dashed lines in Figure 63. If locally the temporal percentile for drainage (63%) would have been used, the corresponding PEC due to spray drift would be 88 mg/m^3, and the countrywide protection level would be 92%. This is indicated by the blue dashed lines in Figure 63. Thus, taking

[27] Note that this is a technique without drift reduction which is not accepted anymore in the Netherlands, but is used here for illustration purposes'.

the higher (drainage) percentile leads to a slightly higher protection, which is higher than the 90th overall percentile.

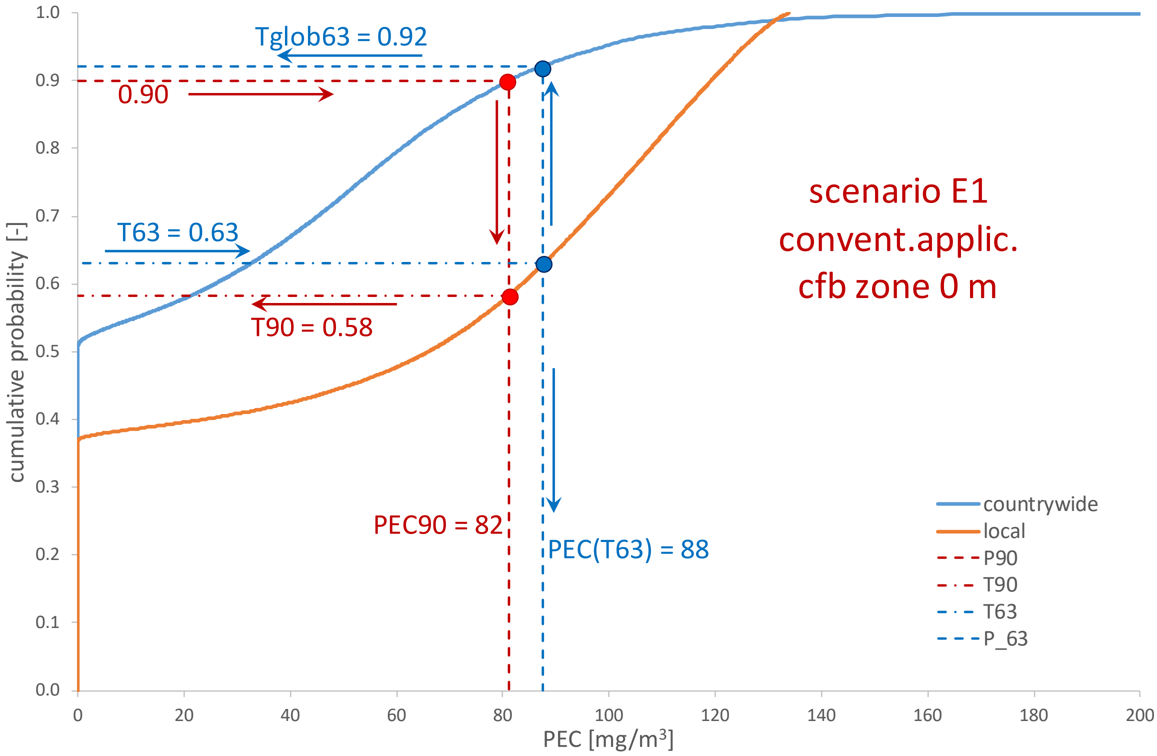

Figure 63 *Cumulative probability density curves for scenario E1, both countrywide/ global coverage (blue curve) and locally for the selected watercourse (orange curve). Red dashed lines connect global 90th percentile protection level with PEC90 and local temporal percentile T90 of 58%. Blue dashed lines connect the local temporal percentile 63% and corresponding PEC value of 88 mg/m^3 and global protection level Tglob63 of 92%.*

Example 2 - scenario S15

For basic scenario S15 (15 applications throughout the growing season), the cumulative probability density functions (cpdf) have a much steeper increase (Figure 64). For a conventional application technique[28] without an additional crop-free buffer zone, the countrywide 90th percentile pesticide concentration (PEC90) is 62 mg/m^3. For the selected watercourse the corresponding temporal percentile is 41%. This is schematically derived through the red dashed lines in Figure 64. If locally the temporal percentile for drainage (63%) would have been used, the corresponding PEC due to spray drift would increase to 65 mg/m^3, and the countrywide protection level would be 92%. This is indicated by the blue dashed lines in Figure 64. Due to the steep local curve, the large step in temporal percentile (from 41% to 63%) has only limited effect on PEC and the countrywide protection level.

[28] Note that this is a technique without drift reduction which is not accepted anymore in the Netherlands, but is used here for illustration purposes'.

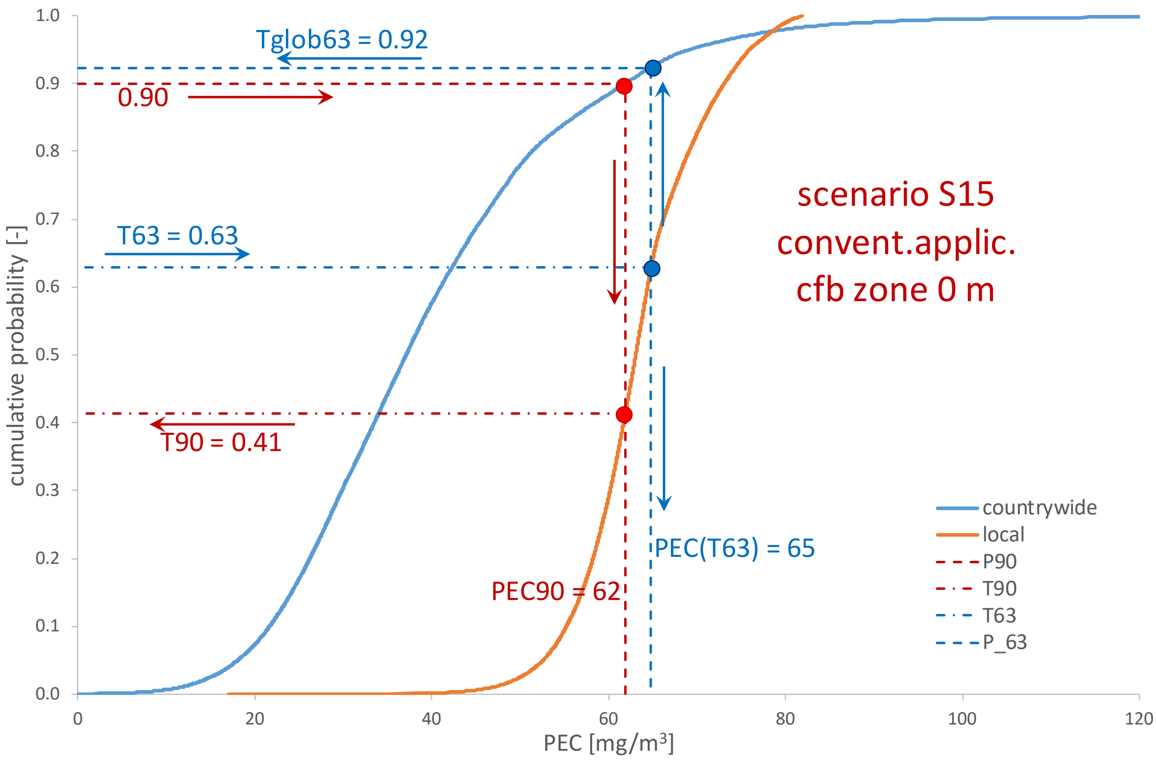

Figure 64 *Cumulative probability density curves for scenario S15, both countrywide (blue curve) and locally for the selected watercourse (orange curve). Red dashed lines connect global 90th percentile protection level with PEC90 and local temporal percentile T90 of 41%. Blue dashed lines connect the local temporal percentile 63% and corresponding PEC value of 65 mg/m^3 and global protection level Tglob63 of 92%.*

Example 3 - scenario L1 with wide crop-free buffer zone

A relatively large effect on PEC and countrywide protection percentile occurs when local temporal percentile for drift and drainage would differ significantly, while the cpdfs would increase only gently. An example of such a situation is given by scenario L1 (a single application in trees in full leaf) with a 9 m crop-free buffer zone (and any application technique would do); see Figure 65 for the cpdf curves. With this scenario, PEC90 is 13 mg/m^3 and the local temporal percentile is 72% (indicated by the red dashed lines in Figure 65). If locally the temporal percentile for drainage (63%) would have been used, the corresponding PEC due to spray drift would decrease to 8.6 mg/m^3, (which is about 34% less than 13 mg/m^3). The countrywide protection level would decrease to 82% (indicated by the blue dashed lines in Figure 65). Due to the only gently increasing local curve, the decrease in temporal percentile (from 72% to 63%) has a significant effect on PEC and the countrywide protection level. Clearly, using the local drainage percentile would lead to less protection (82% countrywide) if spray drift would still be the significant entry route.

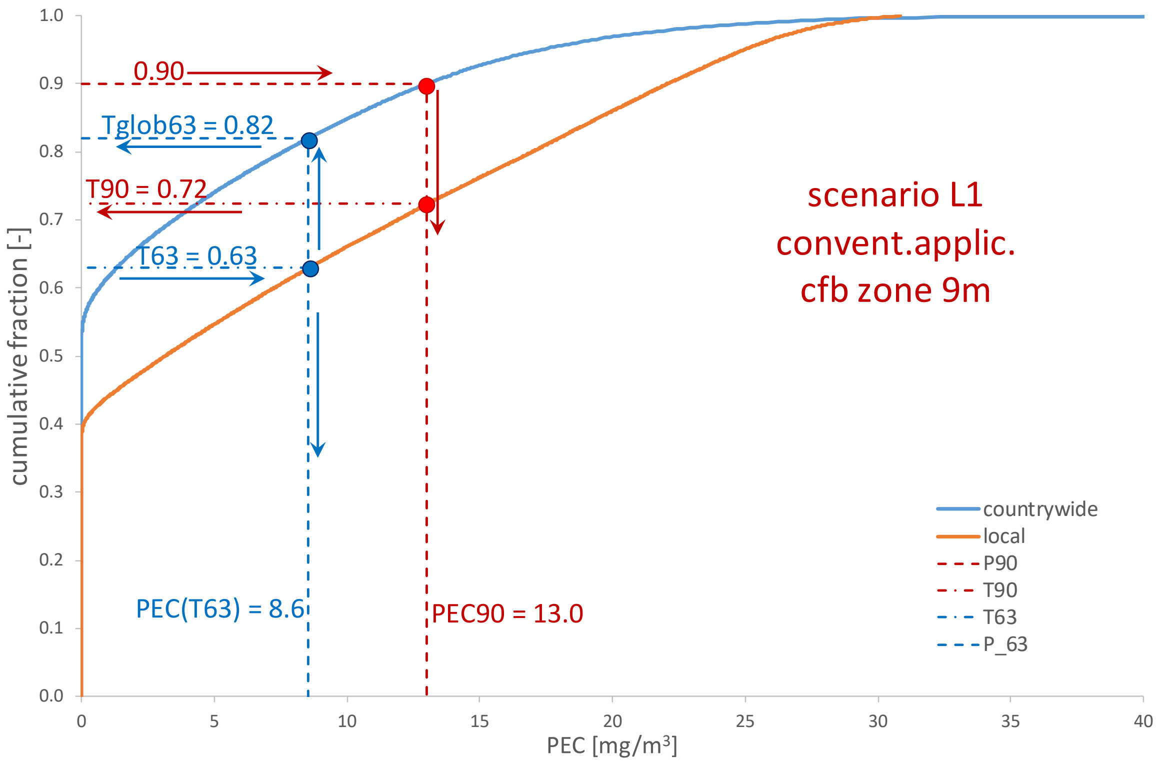

Figure 65 *Cumulative probability density curves for scenario L1, using a conventional application technique and a crop-free buffer zone of 9 m; both countrywide (blue curve) and locally for the selected watercourse (orange curve). Red dashed lines connect global 90th percentile protection level with PEC90 and local temporal percentile T90 of 72%. Blue dashed lines connect the local temporal percentile 63% and corresponding PEC value of 8.6 mg/m^3 and global protection level Tglob63 of 82%.*

Comparing PECs and global protection levels

The above examples indicate that in some cases a change towards the drainage percentile hardly affects PECs and countrywide protection levels, while in other cases the differences may be relatively large. The use of the 63th local percentile was investigated for all basic scenarios (5), combined with all application techniques (7) and crop-free buffer zones (10). Figure 66 shows the ratio of PEC derived from the drainage percentile and the PEC90 as derived for spray drift entries only. A ratio >1 indicates that using the drainage percentile is conservative and gives higher countrywide protection (>90%), while a ratio <1 gives less protection (<90%). The graph shows that in most cases the use of the drainage percentile is conservative if used in situations where spray drift is dominant. However, most scenarios belonging to L1 form an exception: using the drainage percentile is not protective enough in those situations, if spray drift still is dominant.

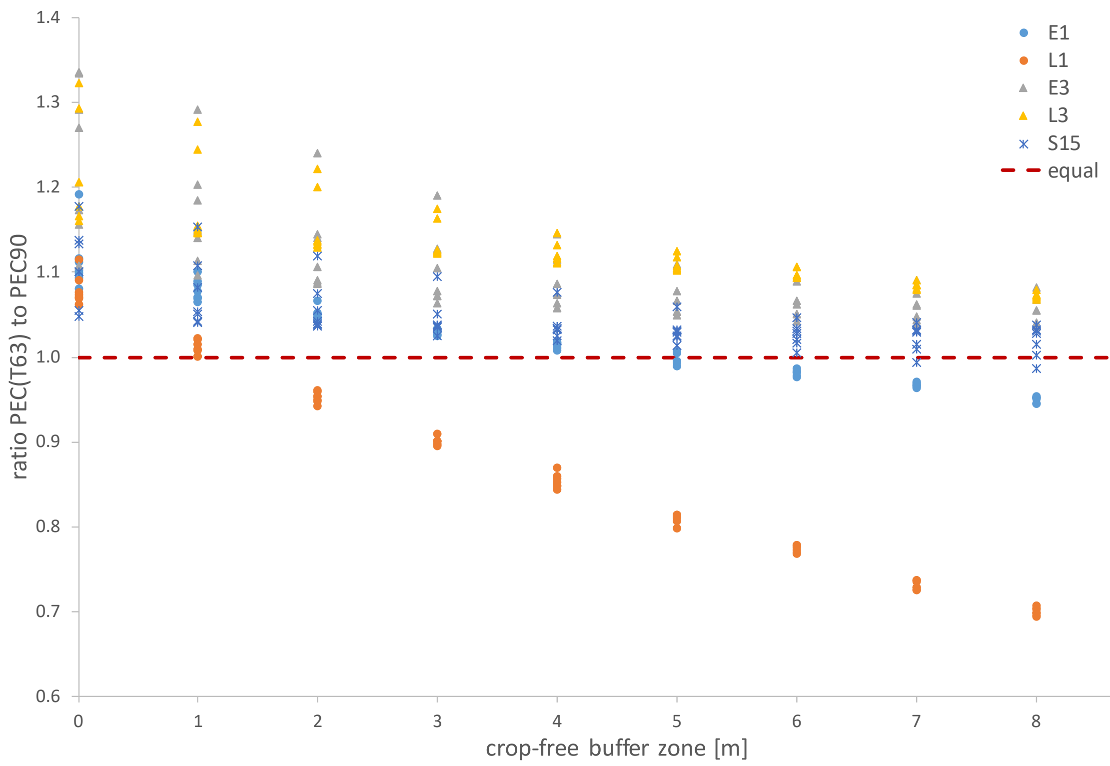

Figure 66 *Ratio of spray drift PECs derived for the drainage percentile (63%) and PEC90 when considering spray drift only. In many cases using the drainage percentile is conservative (ratio >1). However, most scenarios of L1 show the opposite (ratio<1) in which case using the drainage percentile offers less protection when the spray drift entry route is still present. Points A: lowest ratio occurs for cases with L1 and 9m crop-free buffer zone; see text.*

Although an increase in PEC corresponds to a higher protection level, Figure 66 cannot show directly how these protection levels change. This is shown in Figure 67 where countrywide protection levels are plotted for all scenario combinations. Obviously, the same trends as in Figure 66 must show. In many cases, using the drainage percentile of 63% even when spray drift is significant or the major entry route, a conservative protection results (>90% countrywide). Protection level may rise to 96% for some cases of E3 and L3 and to 95% for S15, depending on the application technique. On the other hand, with many cases involving the L1 scenario (typically with increasing crop-free buffer zones), the inconsistent use of the drainage percentile may lead to significant reduction in countrywide protection.

So far, being too protective or, oppositely, being not protective enough, has been judged in a relative way. Either way may be less important in practice when absolute PEC levels would be very low. Therefore, the results of Figure 67 are plotted against PEC90 (assuming spray drift entries only), see Figure 68. This graph indicates that large deviations from the countrywide 90% protection level are not limited to small PEC90s only. It shows that both overprotection and underprotection may occur for a wide range of PEC90 values. Similarly, Figure 66 is adapted to show PEC ratios as a function of PEC90 as well, see Figure 69.

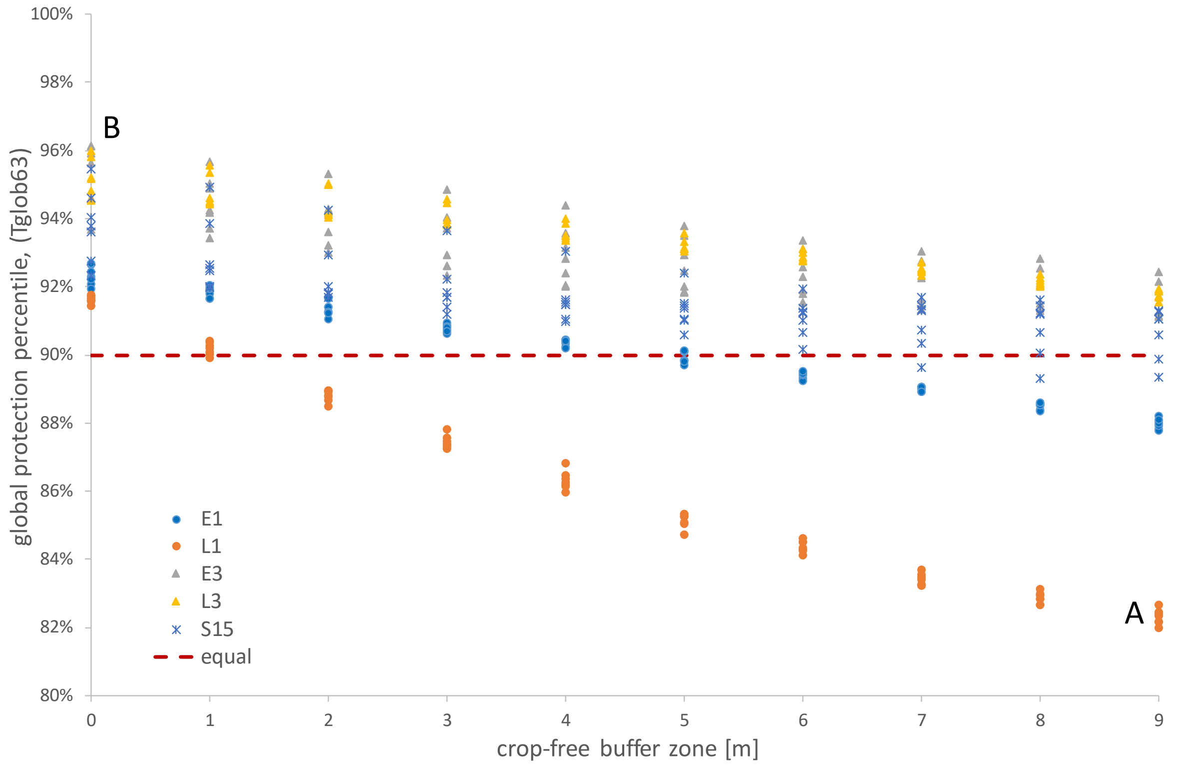

Figure 67 *Countrywide protection level when using the drainage percentile (63%) locally, assuming spray drift still is the major entry route, for all scenario combinations. In many cases using the drainage percentile is conservative (protection level >90%). However, most scenarios L1 show the opposite (protection level <90%). Points A: cases with lowest protection level; point B: case with highest protection level; see text.*

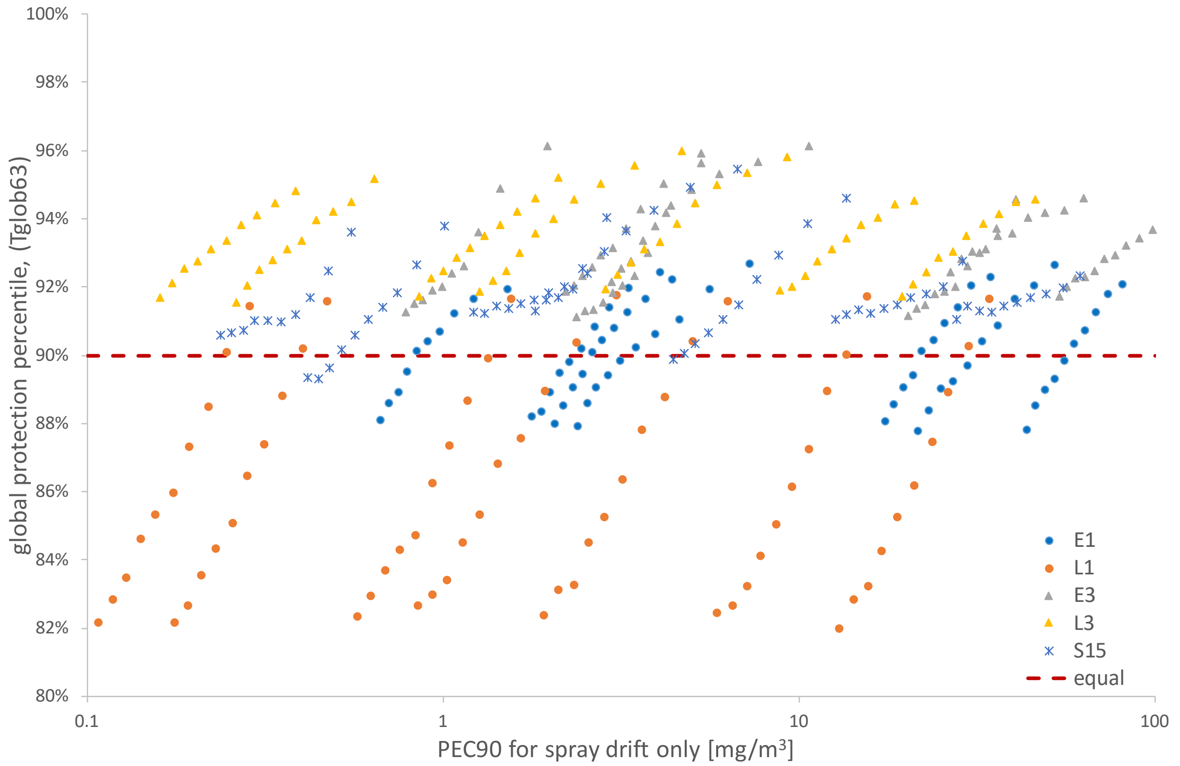

Figure 68 *Countrywide protection level when using the drainage percentile (63%) locally, for all scenario combinations, as a function of PEC90 (when spray drift still is only entry route). Note that the x axis is at a logarithmic scale.*

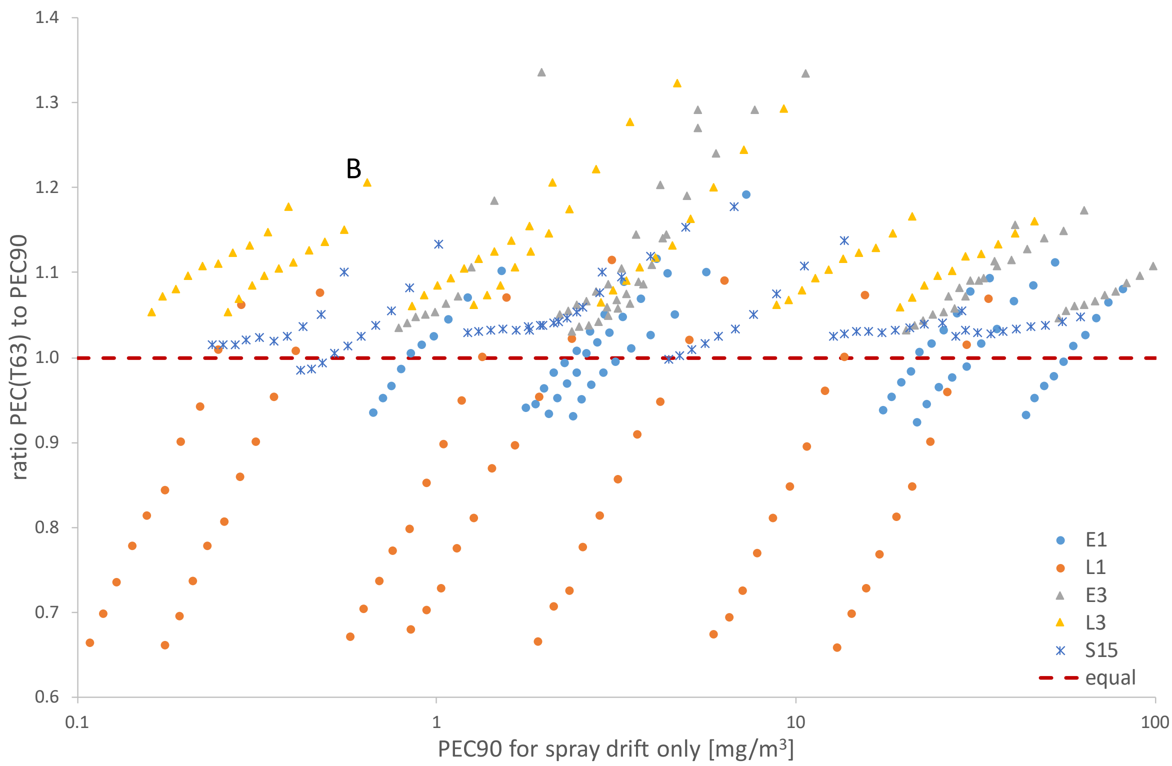

Figure 69 *Ratio of PEC when using the drainage percentile (63%) and PEC90 for situations with spray drift only, for all scenario combinations, as a function of PEC90. Note that the x axis is at a logarithmic scale. Point B: highest ratio when PEC90 is below 1 mg/m^3; see text.*

Annex 4 Consistency check drainage scenario parameterisation

In order to check whether the followed approach for assessing the contribution of spray deposits on tree strips and grass strips results in correct mass balances regarding drainage, the following two sets of calculations with the PEARL model were done.

For calculation set 1 the spatial distribution of the grass and tree strips was accounted for via the input of the dose (approach 1). Therefore a distribution of 27% of the applied mass on the grass strip was assumed adjustment factor of 0.27 for the dose) and 73% on the tree strip (adjustment factor of 0.73 for the dose). The resulting solute fluxes are summed without taking into account the spatial weighting of the grass and tree strips in the orchard, as this is already implicitly accounted for by the factors used.

For calculation set 2 the spatial distribution of the grass and tree strips was taken into account when combining the water and solute fluxes in the drain. Therefore, a dose adjustment factor of 0.4 was used for the grass strip and an dose adjustment factor of 2.2 was used for the tree strip (see Section 4.4 for the derivation of the dose adjustment factors).

Cumulative substance masses from the drain as computed for set 1 and set 2 should be equal, provided that linear sorption of the substance is assumed (i.e. the Freundlich coefficient should be set to 1 for approach 1 to work out properly).

The following input was used in PEARL. Substance properties of example substance In were taken (see Annex 6), however, the DegT50 was set to 1000 d (assuming persistence), the Kom was set to 100 L/kg (assuming mobility) and the Freundlich coefficient was set to 1 (assuming linear sorption). The substance was applied once a year on April 23rd in the orchard with a dose of 1 kg ha-1 (note that it is assumed that this is the dose as given on the pesticide product label, so used in the entire orchard). For both calculations sets crop interception factors used were 0.9 for the grass and 0.726 for the trees.

Most important model input (doses used) and model output (the cumulative substance mass in the drain for the period 1991 -2005) are summarized in Table 8.

Table 8 *Summary of model input and model output of simulations with PEARL for calculation set 1 (spatial distribution grass and tree strips accounted for via dose) and calculation set 2 (spatial distribution grass and tree strips accounted for via combining water and solute fluxes calculated by PEARL for the two strips).*

	Calculation set 1	Calculation set 2
	Model input	
Dose grass strip (kg ha^{-1})	0.26667	0.4
Dose tree strip (kg ha^{-1})	0.7333	2.2
	Model output	
Cumulative mass in drain in the period 91-05; grass strip (g)	1136.8	1705.2
Cumulative mass in drain in the period 91-05; tree strip (g)	3418.1	10254.3
Cumulative mass in drain in the period 91-05; entire orchard(g)	4554.9	4554.9[*, 29]

* areal weighted average, calculated as follows: (2/3)*1705.2 + (1/3)*10254.3.

Both calculation sets finally result in the same value for the cumulative mass in the drains of the orchard in the period 1991-2005. This check shows that the approach followed to take into account the spatial distribution of the grass and tree strips in the orchard is correct.

[29] Note that the postprocessing program made for summing hourly fluxes uses rounded values of the factors (i.e. 0.667 and 0.333). Using these rounded values on the hourly fluxes finally results in a cumulative mass of 4552 gram.

Using the approach of calculation set 1 (approach 1) on substances with non-linear sorption will result in erroneous estimates of the substance mass in the drain water. Therefore, the approach of calculation set 2 (approach 2) is preferred as this approach uses the true substance depositions on the different strips in the orchard.

Annex 5 Graphs drainpipe fluxes

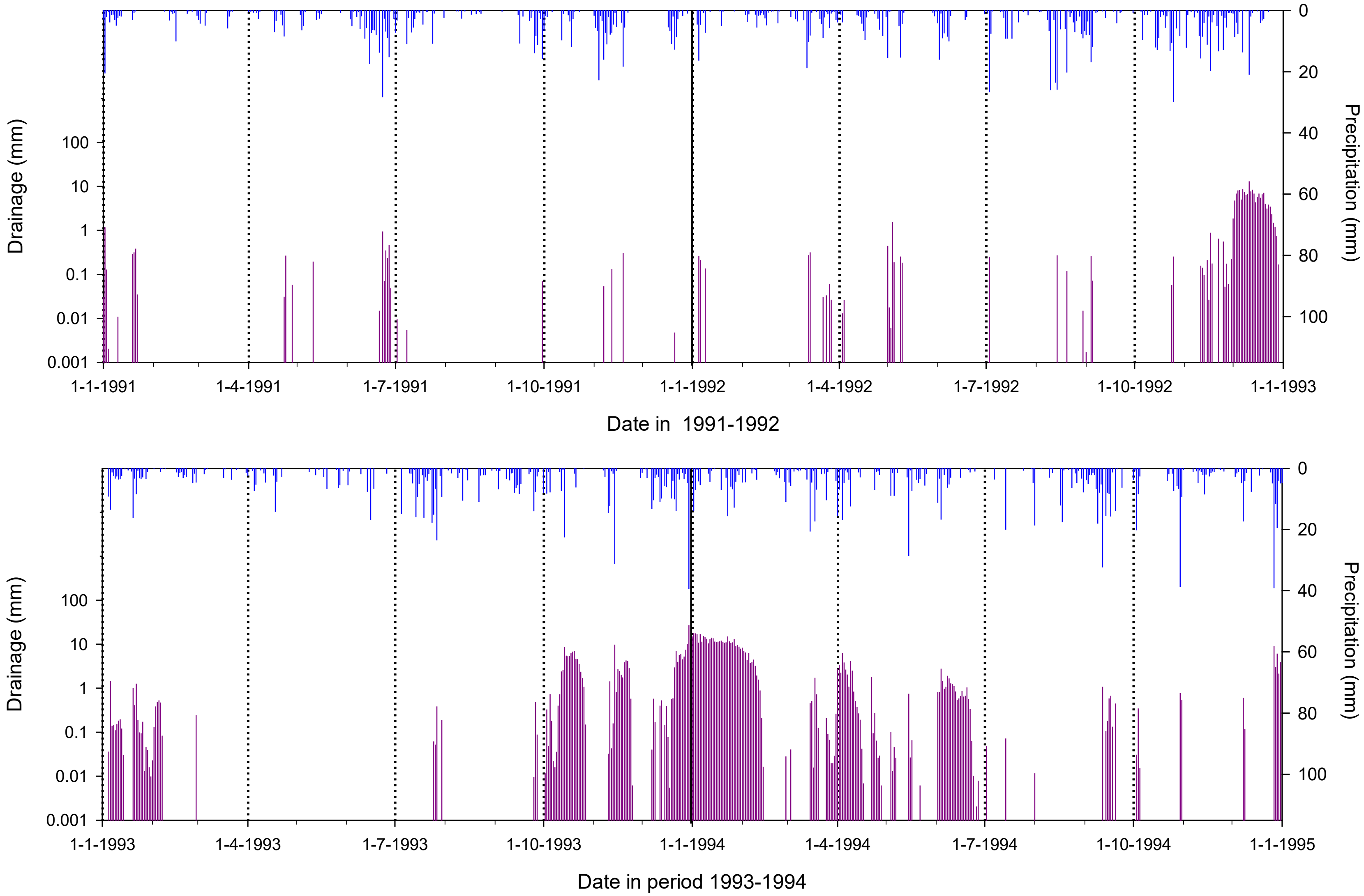

Figure 70 *Rainfall and drainage events as a function of time for the aquatic exposure scenario for upwards and sideways spraying in fruit crops for the periods 1991 - 1992 (top graph) and 1993 – 1994 (bottom graph). Note the logarithmic scale on the y-axis for the drainage.*

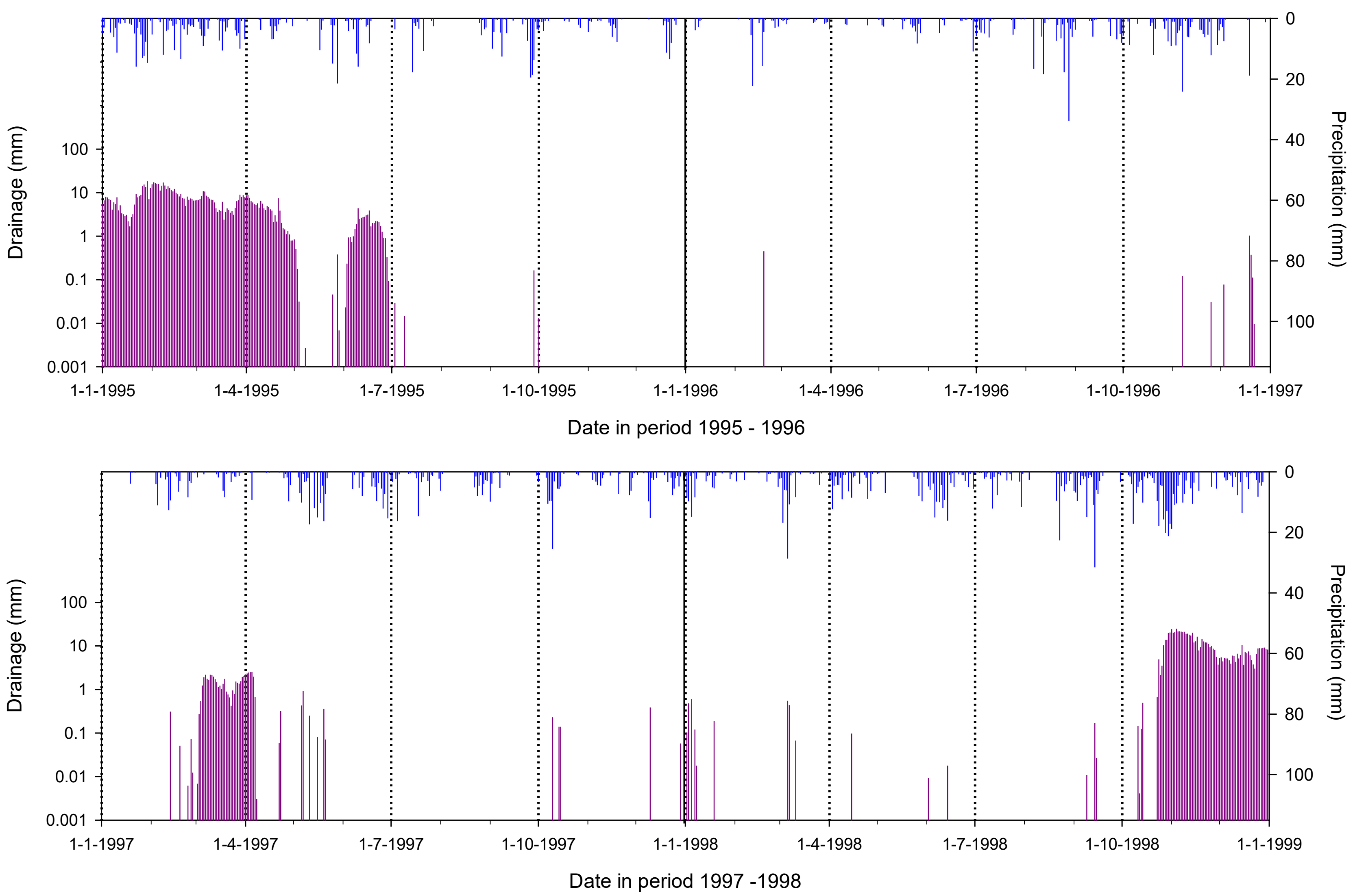

Figure 71 *Rainfall and drainage events as a function of time for the aquatic exposure scenario for upwards and sideways spraying in fruit crops for the periods 1995 - 1996 (top graph) and 1997 – 1998 (bottom graph). Note the logarithmic scale on the y-axis for the drainage.*

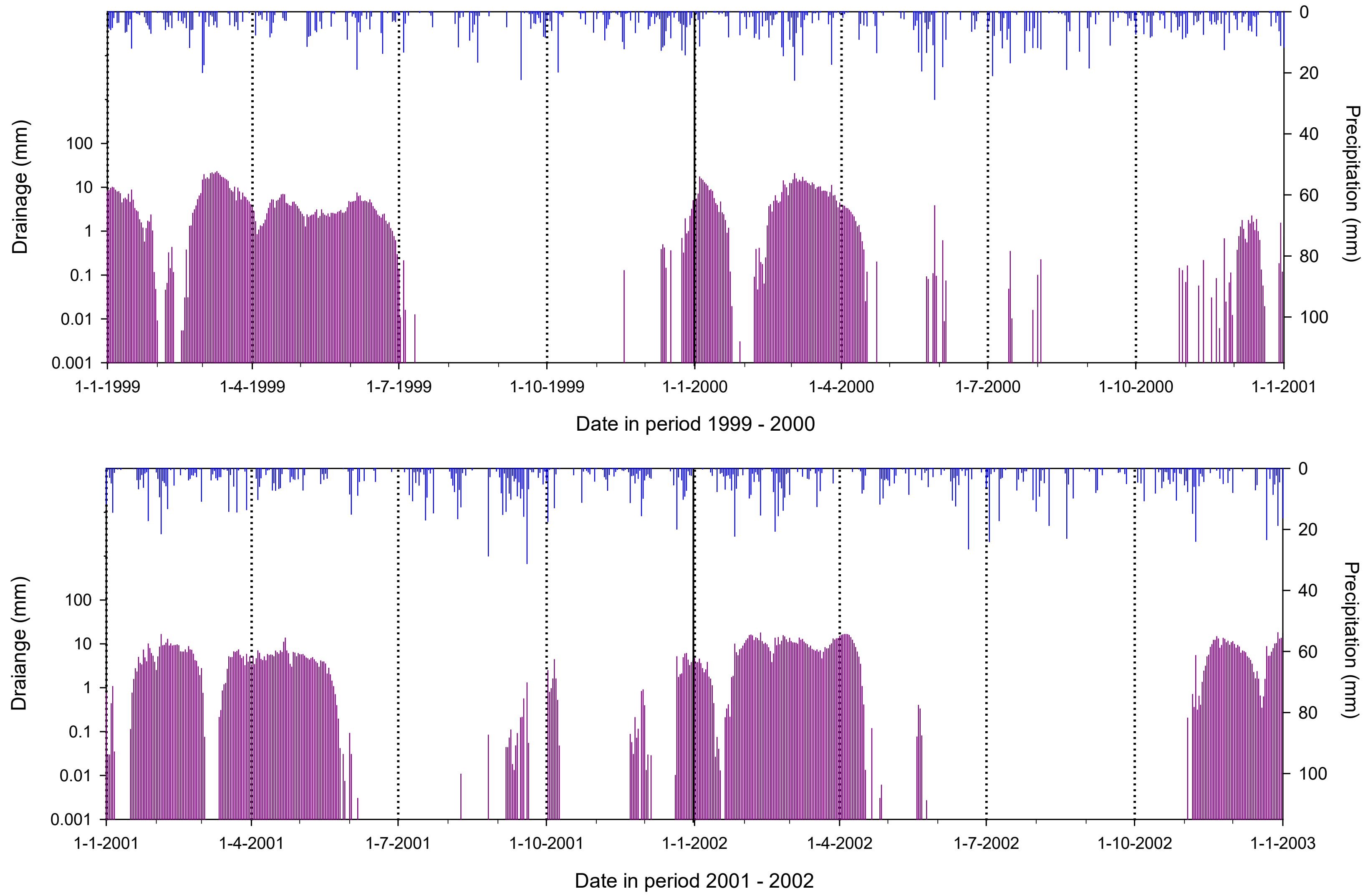

Figure 72 *Rainfall and drainage events as a function of time for the aquatic exposure scenario for upwards and sideways spraying in fruit crops for the periods 1999 - 2000 (top graph) and 2001 – 2002 (bottom graph). Note the logarithmic scale on the y-axis for the drainage.*

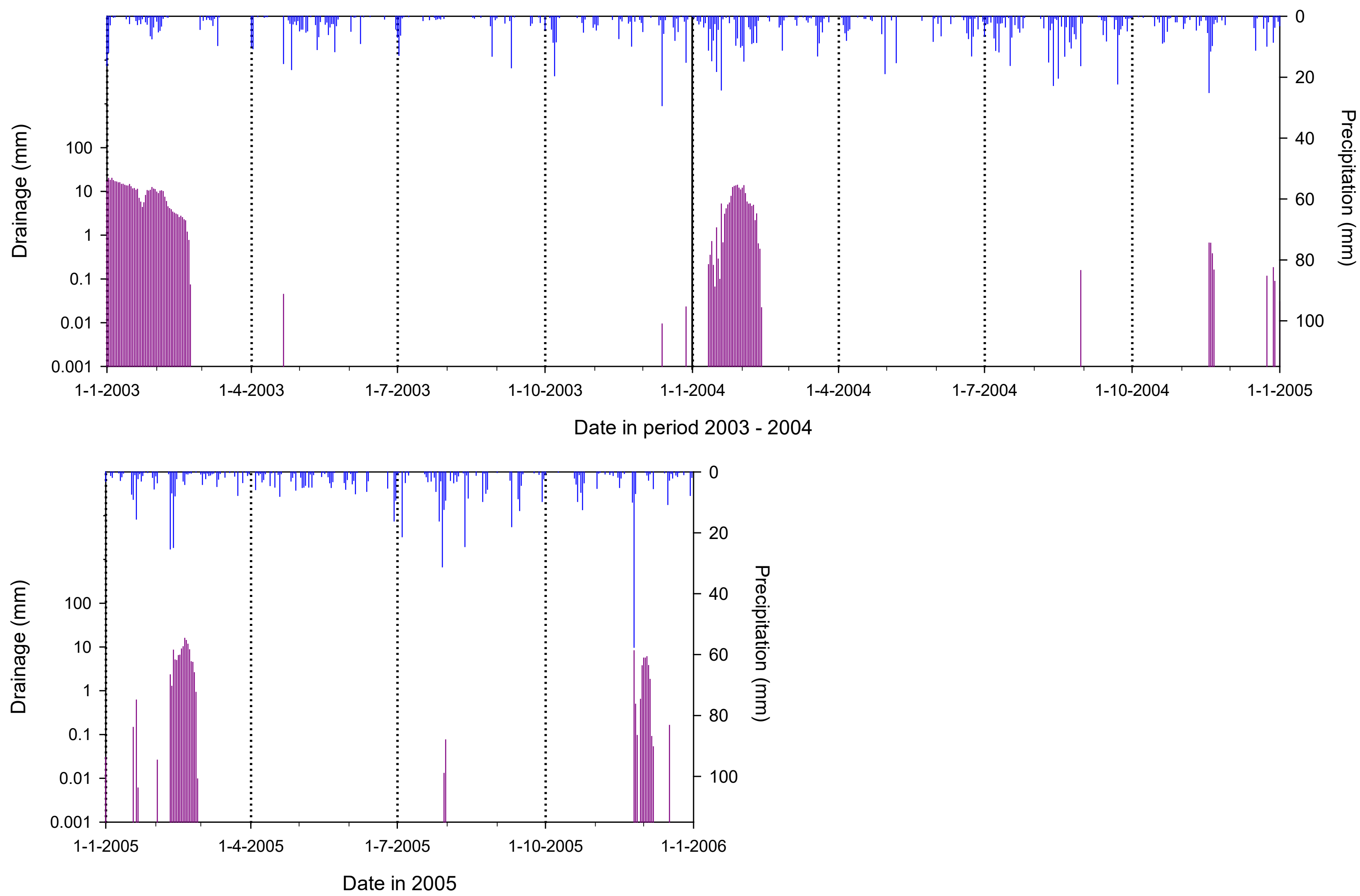

Figure 73 *Rainfall and drainage events as a function of time for the aquatic exposure scenario for upwards and sideways spraying in fruit crops for the periods 2003 - 2004 (top graph) and 2005 (bottom graph). Note the logarithmic scale on the y-axis for the drainage.*

Annex 6 Properties of the example calculation substances

The example substances in this report are real substances. The responsible ministries, however, wanted their names to be listed anonymously. For this reason, a code has been assigned to the substances as follows:

1. substance F is a fungicide from the substance group phthalimides;
2. substance I_N is an insecticide from the substance group neonicotinoids;
3. substance I_P is an insecticide from the substance group pyrethroids;
4. In addition the sensitivity of the drain pipe scenario was assessed. This assessment is largely based on FOCUS SW compound A (Table 6.1-1 in FOCUS, 2001).

Substance properties were derived from the literature or from the list of endpoints (*LoEP*). Only the most important substance parameters were assumed to be substance dependent. All other parameters were assumed to be substance independent, and their values have been taken from the literature. The substance independent data are listed first.

Parameters that were assumed to be substance independent

- E_a for degradation in soil: 65.4 kJ/mol (EFSA, 2007)
- Factor *B* describing moisture dependency of degradation in soil: 0.7 (FOCUS 2000)
- E_a for hydrolysis in surface water: 65.4 kJ/mol (EFSA, 2017)
- Wash-off factor: 100 m^{-1} (0.01 mm^{-1}) conservative value based on EFSA (2017)
- Depth dependency of degradation in soil as proposed by FOCUS (2000)[30]
- Uptake factor for plants: 0.0 (FOCUS 2000)
- Molar enthalpy of vaporisation: 95 kJ/mol (FOCUS 2000)
- Molar enthalpy of dissolution: 27 kJ/mol (FOCUS 2000)
- Molar enthalpy of sorption: 0 kJ/mol (FOCUS 2000)
- Reference diffusion coefficient in water: 0.43×10^{-4} m^2 d^{-1} (FOCUS 2000)
- Reference diffusion coefficient in air: 0.43 m^2 d^{-1} (FOCUS 2000)
- Reference temperatures for diffusion, vapour pressure, water solubility, sorption, transformation rates in soil and water as indicated in the tables below and else 20 ^oC
- Reference moisture content for degradation: pF 2
- *DegT50* for degradation in sediment: we assumed no degradation, so the half-life was set to 1000 d.
- K_{om} for sorption in the sediment and for sorption to suspended solids: we assumed the same value as for soil as listed in the table below.
- Freundlich exponent for sediment: we assumed the same value as for soil.
- Half-life for degradation on plant surfaces: 10 d. EFSA (2017).

[30] i.e. in the PEARL *.prl file the following is done

```
table interpolate FacZTra    (-)            Factor for the effect of depth [0|1]
hor Ip
0.00 1.00
0.30 1.00
0.31 0.50
0.60 0.50
0.61 0.30
1.00 0.30
1.01 0.00
3.20 0.00
end_table
```

		F	I_N	I_P	Compound A
crop		apples	apples	apples	apples
application times and doses	Values	15 x 1.8 kg/ha, start BBCH 68 (day 120 – 30 April) – 7 days interval DRT90	1x 0.15 kg/ha, BBCH 61 day 113 - 23 April), DRT90	3 x 0.0075 kg/ha start BBCH 69 – 7 days interval: 29 April (day 119), 6 May (day 126), 13 May (day 133) DRT90	1 kg/ha (used for sensitivity analysis for application timing, 365 assessments)
Molar mass (g/mol)	Value	300.59	255.7	449.9	300
DegT50 in water due to hydrolysis (d)[31]	Value	0.2 d at pH 7, 25C	1000	1000	1
Kom (L/kg) for soil	Value	56.26	131	138820	5.8
Freundlich exponent (-) for soil	Value	0.9	0.80	0.9	1
DegT50 at 20°C, pF = 2 in top soil (d)	Value	3.82	118	50	3
Water solubility (mg/L)	Value	5.2 at 20°C, pH 7	610 at 20°C	0.005 at 20°C	1 at 20°C
Saturated vapour pressure (mPa)	Value	0.0042 at 25°C	4×10^{-7} at 20°C	0.0002 at 20°C	1.0×10^{-7} at 20°C
pK_a	Value	-	-	-	-

References

Boesten J.J.T.I, P.I. Adriaanse, M.M.S. ter Horst, A. Tiktak and A.M.A. van der Linden, 2015. Guidance proposal for using available DegT50 values for estimation of degradation rates of plant protection products in Dutch surface water and sediment. Wettelijke Onderzoekstaken Natuur en Milieu, Document 284.

EFSA. 2007. Opinion on a request from EFSA related to the default Q10 value used to describe the temperature effect on transformation rates of pesticides in soil. Scientific Opinion of the Panel on Plant Protection Products and their Residues (PPR-Panel). EFSA Journal 622: 1-32.

EFSA (European Food Safety Authority), 2017. EFSA Guidance Document for predicting environmental concentrations of active substances of plant protection products and transformation products of these active substances in soil. EFSA Journal 2017;15(10):4982, 115 pp. https://doi.org/10.2903/j.efsa.2017.4982

FOCUS. 2000. FOCUS groundwater scenarios in the EU review of active substances. EC Document Reference SANCO/321/2000 rev2.

FOCUS. 2001. 'FOCUS Surface Water Scenarios in the EU Evaluation Process under 91/414/EEC'. Report of the FOCUS Working Group on Surface Water Scenarios, EC Document Reference SANCO/4802/2001-rev.2. 245 pp.

[31] Note that for the DT50 in waterUse of the DegT50water from hydrolysis studies is based on the first tier of the guidance of Boesten et al. (2015) for deriving the DegT50 in surface water from different types of study via a stepped approach.

Annex 7 Sediment characterisation

The sediment properties used for the example calculations are based upon measured sediment properties in ditches alongside Dutch arable crops fields (Adriaanse et al., 2015). From the measured sediments, those of the locations Benschop (high organic matter content and low bulk density) and Willemstad (lower organic matter content and relatively higher bulk density) were selected because these are the two extremes with respect to sediment properties. The impact of sediment properties on pesticide fate and behaviour in the scenario ditch are assessed by performing calculations with these two sediments and example substance I_p. Below the sediment characterisation as used in TOXSWA is provided. Willemstad sediment properties were selected for the scenario parameterisation.

Table 9 *Sediment discretisation (standard) and sediment properties based on Benschop sample location.*

Sediment horizon ID	Thickness of the sediment horizon (m)	Number of numerical layers in the sediment horizon	Dry bulk density (kg.m-3)	Organic matter content (kg.kg-1)	Porosity (m3.m-3)	Tortuosity (-)
1	0.004	4	120	0.22	0.94	0.89
2	0.006	3	120	0.22	0.94	0.89
3	0.01	2	200	0.24	0.92	0.86
4	0.03	3	200	0.24	0.92	0.86
5	0.02	1	200	0.24	0.92	0.86
6	0.03	1	200	0.24	0.92	0.86

Table 10 *Sediment discretisation (for substances with a high sorption coefficient) and sediment properties based on Benschop sample location.*

Sediment horizon ID	Thickness of the sediment horizon (m)	Number of numerical layers in the sediment horizon	Dry bulk density (kg.m-3)	Organic matter content (kg.kg-1)	Porosity (m3.m-3)	Tortuosity (-)
1	0.00024	8	120	0.22	0.94	0.89
2	0.00012	2	120	0.22	0.94	0.89
3	0.0001	2	120	0.22	0.94	0.89
4	0.00024	2	120	0.22	0.94	0.89
5	0.0003	1	120	0.22	0.94	0.89
6	0.0015	2	120	0.22	0.94	0.89
7	0.004	2	120	0.22	0.94	0.89
8	0.0035	1	120	0.22	0.94	0.89
9	0.01	2	200	0.24	0.92	0.86
10	0.03	3	200	0.24	0.92	0.86
11	0.02	1	200	0.24	0.92	0.86
12	0.03	1	200	0.24	0.92	0.86

Table 11 *Sediment discretisation (standard) and sediment properties based on Willemstad sample location.*

Sediment horizon ID	Thickness of the sediment horizon (m)	Number of numerical layers in the sediment horizon	Dry bulk density (kg.m-3)	Organic matter content (kg.kg-1)	Porosity (m3.m-3)	Tortuosity (-)
1	0.004	4	320	0.124	0.83	0.73
2	0.006	3	320	0.124	0.83	0.73
3	0.01	2	490	0.101	0.78	0.67
4	0.03	3	490	0.101	0.78	0.67
5	0.02	1	490	0.101	0.78	0.67
6	0.03	1	490	0.101	0.78	0.67

Table 12 *Sediment discretisation (for substances with a high sorption coefficient) and sediment properties based on Willemstad sample location.*

Sediment horizon ID	Thickness of the sediment horizon (m)	Number of numerical layers in the sediment horizon	Dry bulk density (kg.m-3)	Organic matter content (kg.kg-1)	Porosity (m3.m-3)	Tortuosity (-)
1	0.00024	8	320	0.124	0.83	0.73
2	0.00012	2	320	0.124	0.83	0.73
3	0.0001	2	320	0.124	0.83	0.73
4	0.00024	2	320	0.124	0.83	0.73
5	0.0003	1	320	0.124	0.83	0.73
6	0.0015	2	320	0.124	0.83	0.73
7	0.004	2	320	0.124	0.83	0.73
8	0.0035	1	320	0.124	0.83	0.73
9	0.01	2	490	0.101	0.78	0.67
10	0.03	3	490	0.101	0.78	0.67
11	0.02	1	490	0.101	0.78	0.67
12	0.03	1	490	0.101	0.78	0.67

Annex 8 Adjustment of the scenario output for small fruit

Since for small fruit (with upward and sideways treatments) no explicit experimental data on spray drift deposits are available, for scenarios involving small fruit a different approach is necessary. According to previous agreement (Evaluation Manual Ch 6, Ctgb, 2020), spray drift deposits for small fruit are set to the values for large fruit (pome and stone fruit orchards) when these are in full leaf. These values for small fruit should be used on any day of the year. Previously, there was only one set of drift data for large fruit in full leaf (for May 1 and beyond).

In DRAINBOW, the results of the SPEXUS drift model will be used for determining downwind spray drift deposits for large fruit. Within this model, the spray drift deposits depend on the growth stage of the fruit tree canopy (based on BBCH index) and therefore these deposits depend on the application day of year (DOY). Consequently, the full leaf period no longer has fixed drift deposit values but these values now gradually change during the year. So there is no single full-leaf drift value for large fruit. The next question is in which way scenarios for small fruit are to be incorporated.

One option is to stick to the full leaf situation and select a day in mid-summer (July) when the canopy of large fruit is most dense; the corresponding spray drift values can be used for small fruit throughout the year. However, these spray drift values may be too low to represent small fruit in a dormant (leafless) stage. Another option is to use the SPEXUS model as it is for both large and small fruit, including the dependence on changing canopy density throughout the year. While this is fine (and still conservative) in summer, in the dormant (leafless) period this is likely to be too conservative, as the spray drift values for large fruit probably are too high to represent dormant small fruit adequately. It also does not comply with the current agreement to use the large fruit full-leaf drift values for small fruit.

Therefore the following workaround has been chosen. The SPEXUS model provides the two dates where the canopy of large fruit is at 50% of its full density. These dates are June 6 and November 4. On and between those dates, the canopy has a density of at least 50% (up to 100%) of its full mid-summer density. This period can be considered as the 'full leaf period' of the year. Since canopy density, within this period, is lowest at June 6 and November 4, spray drift deposits must be highest and therefore conservative on those days. It turned out that spray drift deposits on June 6 are higher than those on November 4, due to different meteorological conditions. Therefore, between June 6 and November 4 the SPEXUS drift values for large fruit are used for small fruit as well, while from November 5 until June 5 (included) the conservative full-leaf drift values of June 6 are used for small fruit.

Figure 1 shows an example of PEC values due to spray drift deposits on the selected waterbody during the year. For convenience, a temporal percentile of 60% is used throughout to determine the PEC values; this approximates the percentile for the scenarios with one spray application and crop-free zone of 3.0 m. The red curve for large fruit (DRT75, crop-free zone 4.5 m) lies below the dashed blue curve to be used for small fruit (DRT75, crop-free zone 3.0 m), since the crop-free zone is narrower in the latter case. Using the above mentioned workaround, the PEC on June 6 is the highest of the full-leaf period and can be used for small fruit before June 6 (up to week 22) and after November 4 (week 45 and beyond); this is shown in the solid blue curve.

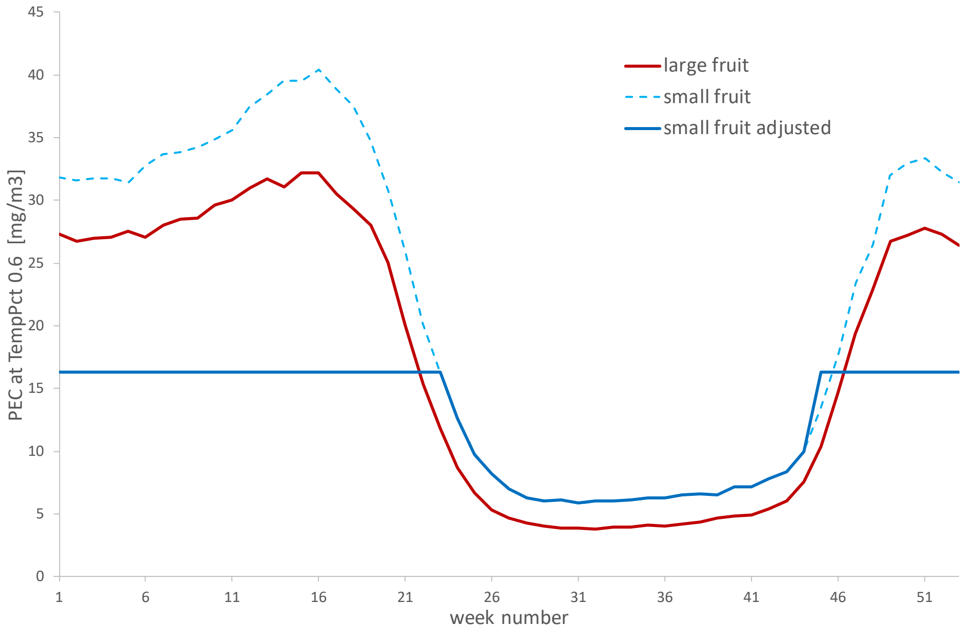

Figure 74 *Example of PEC values due to spray drift deposits on the selected waterbody for each week of the year, computed using SPEXUS for large fruit with DRT75 and a crop-free zone of 4.5 m (red curve), for a temporal percentile of 60% throughout. Equivalently, for small fruit the same model is used with crop-free zone of 3.0 m (blue dashed curve). When before June 6 and after November 4 the PEC value of June 6 is used, the solid blue curve is obtained for small fruit.*

Annex 9 Sensitivity to the application timing and EU FOCUS scenarios

The approach of not allowing the registrant to select application dates, but to specify only the BBCH crop development stages during which the application(s) should take place according to the GAP corresponds to what is done in the 'repaired' EU FOCUS surface water scenarios. The GAP, Good Agricultural Practice, specifies the application table as given in the request of the applicant or on the label of a product. Note further that linking the application to the BBCH crop growth stages mentioned in the GAP corresponds well to the request of the applicant and the formulation on the label.

Although the situation is quite different for the single Dutch fruit scenario and the 10 EU FOCUS scenarios their situation with respect to (i) robustness and (ii) level of protection of calculated PEC_{sw} values (originating from drain inputs) is rather similar.

Concerning (i) robustness:
In the EU FOCUS scenarios the application dates are 'moved around' in a 7-d application window, in order to avoid unrealistic application days with rainfall. The so-called PAT, Pesticide Application Timer, thus improves the realism and also the robustness of PEC_{sw} values by eliminating the days with more extreme conditions (such as the extremely cracking clay soils with rainfall of scenario D2 or days with heavy rainfalls of scenario R2 as shown in section I.3 and, to a lesser extent K.1 of EFSA (2020).

In the NL scenario environmental conditions appear to be less extreme than those used in EFSA (2020). However, for drain dominated situations PEC_{sw} values (referred to as PEC90 in this report) vary considerably too if the application date changes by one or two days, due to the inherently event-driven nature of drainflow in soils having macropores, as shown in section 6.7 of this report.

So, to avoid variations in the PEC_{sw} values as much as possible, both the NL scenario and the EU FOCUS scenarios oblige the use a fixed application day (NL scenario) or a selected day in a fixed small application window (EU FOCUS scenarios).

Concerning (ii) level of protection:
In practice applications are set by the software at the beginning of the period which corresponds to mentioned BBCH crop growth stage and hence, not the entire relevant BBCH window is covered. Thus the calculated PEC_{sw} value may not represent the 'realistic worst-case' value, not in the NL scenario, nor in the EU FOCUS scenarios[32].

[32] The FOCUS scenarios allow for a 'backward' selection of the application date too, by placing the 7-d application window at the end of the BBCH crop growth stage, thus attempting to increase the likelihood of calculating a 'realistic worst-case' PECsw value.

Wageningen Environmental Research
P.O. Box 47
6700 AA Wageningen
The Netherlands
T +31 (0)317 48 07 00
www.wur.nl/environmental-research

Wageningen Environmental Research
Report 3100
ISSN 1566-7197

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 6,800 employees (6,000 fte) and 12,900 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

To explore the potential of nature to improve the quality of life

Wageningen Environmental Research
P.O. Box 47
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 07 00
www.wur.eu/environmental-research

Report 3100
ISSN 1566-7197

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 6,800 employees (6,000 fte) and 12,900 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.