

SCIENTIFIC OPINION

Draft Scientific Opinion on clustering and ranking of emissions of plant protection products from protected crops (greenhouses and crops grown under cover) to relevant environmental compartments¹

EFSA Panel on Plant Protection Products and their Residues (PPR)^{2, 3}

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ABSTRACT

The Scientific Panel on Plant Protection Products and their Residues (PPR Panel) of EFSA was asked to make an inventory of protected crop systems (e.g. greenhouses and cultivations grown under cover) and emissions from these systems to relevant environmental compartments, and to provide guidance on the importance of emission routes including the circumstances under which they are relevant. This opinion identifies greenhouses and walk-in tunnels having priority for scenario development. For these covered crop systems, the PPR Panel recommends the development of tiered risk assessment procedures. Further investigation is necessary to find out whether risk assessment for open field may be used as the first tier in these procedures. The opinion furthermore addresses elements that should be considered in deriving the risk assessment scenarios, for both soil-bound and soil-less cultivations.

KEY WORDS

risk assessment, protected crop, covered crop, environmental fate, pesticide, glasshouse, environmental receptor

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SUMMARY

A number of EU Member States (MSs) requested guidance on how to carry out environmental risk assessment of Plant Protection Products (PPPs) emitting from protected crops in response to EFSA's consultation of MSs. Following this request, the Scientific Panel on Plant Protection Products and their Residues (PPR Panel) of EFSA was asked to develop an inventory of protected crop systems (e.g. greenhouses and cultivations grown under cover) and emissions from these systems to relevant environmental compartments, and to provide new guidance on the importance of emission routes including the circumstances under which they are relevant.

Previous investigations have shown that emissions to environmental receptors do occur, even from high technology greenhouses. Based on these investigations and further considerations regarding the emission driving forces, the following conclusions could be drawn:

Receptor air

Although non-conclusive because different modelling approaches for open field and protected crop systems had to be used, current information suggests that emissions from all protected crop systems to the receptor air occur and might have the same order of magnitude as for the open field. However, as a protection goal for the air compartment is missing, a recommendation for further model and scenario development cannot be given.

The authorisation procedure for open field applications requires the assessment of the potential long-range transport via the assessment of the half-life of substances in air. As emissions from covered crops systems to the air compartment do occur depending on substance properties, it is recommended to require this also for covered crop applications.

Receptor groundwater

Leaching to groundwater from protected crop systems may occur, depending on environmental conditions and substance properties. For a high-tech greenhouse, the calculated leaching appeared to be lower than in comparable open field situations. The higher temperature (annual average) appeared to be the major factor in the lower leaching. Only closed walk-in systems are expected to have higher annual average temperatures. For open walk-in structures and low structures, the leaching is expected to be closer to the leaching from open field under otherwise comparable circumstances.

Receptor surface water

Spray drift emissions to surface water from walk-in tunnels were calculated to be in the same order of magnitude as drift emissions from open field applications, when holes are made in the cover and the sides rolled up. As a conservative approach for risk assessment, emission percentages as established for open field applications can be used, for downward respectively upward/sideways application techniques as appropriate, for all covered cropping systems except for greenhouses. When windows are closed during application, drift emissions will be absent in greenhouses.

The conclusions drawn for leaching after application to soil-bound crops can be extrapolated to drainage to surface water.

Condensation is a potential emission route in protected crop systems, for which there is no equivalent route in open field systems. If the condensation is collected and reused as a water source in soil-bound cultivation, there will be no significant additional emission to surface water or groundwater. If the collected condensation is not reused or the condensation flows directly to surface water, the emission of PPP might be significant. The currently used emission percentage for condensation seems to undervalue the emission and needs to be reconsidered. The condensation route has to be considered when selecting or developing scenarios for greenhouses.

64 Soil-less cultivation has no equivalent in the open field. Scenarios for emissions to surface water need
65 to be developed for these growing systems.

66 General conclusions

67 The following systems were identified as having priority in developing risk assessment methodology:

construction	system	application	emission	receptor
greenhouse	soil no recirculation	spray	leaching/drainage	groundwater
			condensation	surface water
			gas phase emission at application	
walk-in tunnel	soil no recirculation	spray	gas phase emission at application	groundwater
			drift	surface water
			leaching/drainage	
greenhouse	soil-less with recirculation	drip irrigation	discharge	surface water
		spray		
greenhouse	soil-less without recirculation	drip irrigation	discharge	surface water
		spray	condensation	

68

69 Emissions from soil-bound cultivations in walk-in tunnels as well as both soil-bound and soil-less
70 cultivations in greenhouses may substantially differ from those in the open field. Relevant factors to
71 consider in the scenario development are the climatic conditions, soil characteristics (if applicable) and
72 soil hydrology, the quality of the water sources and management practices with regard to inside
73 climate, irrigation / water supply and discharge.

74 When developing risk assessment methodology for the soil-bound cultivations indicated in the table
75 above, it may be investigated whether risk assessment methodology for the open field could perhaps
76 serve as a first tier. One should be aware, however, that the spatial distribution of the population may
77 deviate from that of the open field.

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BACKGROUND AS PROVIDED BY EFSA

Protected crops (e.g. greenhouses and cultivations grown under cover) are specified in the Directive 91/414/EEC as amended, for fields of use of both chemical and microbial products. During the review process of the substances of the second and third list, concerns were raised by Member States regarding the lack of guidance for the environmental exposure assessment for protected crops.

There is no definition that demarcates the emission of a protected crop application from the emission of a field application. Neither is there agreement on the definitions of individual protected/covered crop systems like a specific type of greenhouse. Nevertheless, several active ingredients have been listed in Annex I with reference to use in greenhouses, in one case specifying a closed hydroponic system.

A number of Member States have expressed interest in development of guidance documents in this area in response to a consultation on Guidance Documents by the Director of Sciences from EFSA in his letter of 3 July 2006 sent *via* the Standing Committee on the Food Chain and Animal Health.

The foreseen guidance will allow a future working group to develop emission and exposure scenarios. EFSA intends to consult Member States and stakeholders to collect comments during the development of the Guidance Document.

TERMS OF REFERENCE AS PROVIDED BY EFSA

The Scientific Panel on Plant Protection Products and their Residues (PPR Panel) of EFSA is asked to develop an inventory of protected crop systems (e.g. greenhouses and cultivations grown under cover) and emissions from these systems to relevant environmental compartments, and to provide guidance on the importance of emission routes including the circumstances under which they are relevant.

1. Introduction

In the current EU regulation⁴, protected crop systems (e.g. greenhouses and cultivations grown under cover) are considered as systems which prevent emission of PPPs after application. Nevertheless, there are indications from research reports and other literature (see, for example, Teunissen, 2005) that emissions may occur in some cases, and therefore the PPR Panel was asked to formulate guidance for handling these concerns.

The Panel developed an initial Project Plan, which was amended and finalised after a public consultation with experts and stakeholders (EFSA 2009; EFSA 2010a). The Panel decided to follow a phased approach: a preliminary phase in which necessary information is gathered, followed by a guidance development phase, if deemed necessary. The preliminary phase provides / will provide an overview/inventory of covered cropping systems, with a view to:

1. Identify and describe system characteristics that are required to classify protected crop systems (EFSA 2010c), procurement reports on data collection (EFSA 2010f, EFSA 2010g, EFSA 2010h and EFSA 2011).
2. Identify potential emission routes and the relevance of these for the classes of covered production systems (and under which conditions these are applicable) (EFSA 2010c, this Opinion, Appendix this Opinion, Beulke *et al.* 2011).
3. Provide the relevant information so as to enable ranking of emissions, which can serve for the development of exposure scenarios and risk assessment schemes for protected cropping systems in a subsequent Working Group (WG) (this Opinion, Beulke *et al.* 2011, Stanghellini 2009, Van der Linden 2009).

⁴ Regulation (EC) 1107/2009

4. Identify environmentally relevant data on land use intensity for the given types of protected cropping (procurement reports data collection (EFSA 2010f, EFSA 2010g, EFSA 2010h and EFSA 2011), EFSA database, Appendix to this Opinion).

5. Enable competent authorities to decide what classifications have practical use with respect to inclusion of pesticides in Annex I (Directive 91/414/EEC) and approvals of substances in Regulation (EC) 1107/2009 and national authorisations.

In the first opinion (EFSA 2010c), a survey of the covered crop systems was given and a classification system for structures was developed according to six major groups: low (mini) tunnels, plastic shelters, net shelters, shade houses, walk-in tunnels and greenhouses (low- and high tech types). Also the emissions routes and the major receptors were defined in relation to the structure of the cover, the pesticide application method and the soil/soil-less growing system. This classification system is considered useful in describing the huge variability of the sector and used throughout this Opinion as well.

As stated above under points 2 and 3, this Opinion addresses potential emission routes, their relevance and their ranking. More specifically, the aim of this Opinion is to identify those situations for which scenario development is useful and/or necessary and to prioritise them. The approach is according to two aspects: 1) emission, and 2) location. With regard to the emission aspect, estimations of emissions from selected covered crop systems to environmental receptors are compared to emissions from open field applications. With regard to the location aspect, the distribution of covered cropping systems is compared to that of open field cropping systems as far as driving forces for emissions are concerned (see chapter 3). Besides this, the Opinion identifies models that can be used for calculating emissions from covered crops (chapter 2) and major aspects to be considered when actually developing scenarios (chapter 4).

In this opinion, only emissions of plant protection products applied to crops grown under cover are discussed. In the earlier opinion on this subject (EFSA 2010c), it was recognised that emissions from covered cropping systems might occur due to removal of crop remnants, harvested products, substrates and plastic materials. The Panel does not consider these emissions in this Opinion because in most member states dedicated regulations, not related to Regulation 1107/2009, on these aspects are in force. Assessment with regard to consumers, occupational and residential exposure is explicitly excluded in this Opinion.

2. Overview of models for calculating emissions

Emissions of Plant Protection Products from protected crops to different environmental compartments can be different from emissions in open fields. Therefore development of specific environmental risk assessment strategies for protected crops may be necessary in some cases (EFSA, 2010c). These emissions are governed primarily by the physicochemical properties of the applied compounds, the characteristics of the covered structures, the covered structure management including application techniques, ventilation frequency and techniques and the outside climatic conditions (FOCUS, 2008). Consequently, modelling approaches to estimate emission of PPPs from protected crop systems to the various receptors (air, groundwater, surface water, soil) have to consider these important factors influencing emissions from protected crops.

As far as known, there is no single model capable of calculating emissions from protected crops systems to all environmental receptors. Approaches taken so far have combined two or more models to achieve results. Depending on the receptor and the major emission driving forces, a series of models (or modules) are necessary to calculate emissions and resulting concentrations in environmental receptors:

1. a model for calculating climatic conditions within the structure, taking into account outside climatic conditions with, for example, the ventilation rate of the structure as a result;

2. a model for calculating the crop water requirement;
3. a model for distributing water to the crop, based on available water sources and the quality of the water;
4. depending on the growing system, a model for calculating water discharge (drainage) or leaching from the system;
5. models for calculating resulting concentrations in the receptors: air, groundwater, soil and surface water.

When emissions from covered structures must be estimated, first the **climatic conditions** within the covered structures must be simulated. In principle, covered structure climate simulation models quantitatively describe the relations and the interactions between greenhouse crop processes (photosynthesis and transpiration) and indoor and outdoor climate, accounting for the effects of greenhouse structure, physical properties of cover materials, outside weather conditions, and action of controllers (Hemming *et al.*, 2007). Until now, several decision support systems have been developed such as KASPRO (De Zwart, 1996), SERRISTE (Tchamitchian *et al.*, 2006) and HORTEX (Rath, 1992, 2006).

KASPRO (De Zwart, 1996) is an extensive dynamic simulation model which simulates a full-scale greenhouse based on the greenhouse construction elements, ventilation openings, greenhouse equipment, different covering materials and their properties (transmission, reflection, and emission), set-points for inside climate and the outside climate of a given location. The model is based on the computation of relevant heat and mass balances, including both convection and irradiation processes. SERRISTE (Tchamitchian *et al.*, 2006) is a decision making system that generates daily climate set points for greenhouse grown tomatoes. The system is based on the mathematical formalisation of expert practices and scientific knowledge, as a constraint satisfaction problem. HORTEX (Rath, 1992, 2006) is a computer based decision support system for the design and operation of greenhouse heating systems, to estimate the heating energy consumption. The thermal demand in HORTEX is calculated using arithmetic calculations. Greenhouse climate models can be a starting point for estimating emissions from protected crop systems as they simulate the ventilation rate of the greenhouse. The ventilation rate is the major driving force for emissions to air, which also influences emissions to other receptors.

Quantifying **water fluxes** in a covered structure can be of great importance especially when emissions of plant protection products to groundwater or surface water must be estimated. The WATERSTROMEN model (Bezemer and Voogt, 2008) estimates the incoming and outgoing water flows at a commercial nursery during a year or a growing cycle of a crop (Vermeulen *et al.*, 2010). The WATERSTROMEN model has been developed for modelling of the water flows within soil-less systems but it can also be used for soil-bound cultivations. The model uses the transpiration model from De Graaf (1988) and some modifications introduced by Voogt *et al.* (2000) and parameters to simulate the **water uptake for crop growth**. Climate data such as temperature, the sum of radiation and precipitation as well as related greenhouse climate data are used as input. A number of parameters are used to calculate the various water fluxes on a daily basis. The model can be used to calculate the actual (daily) irrigation volumes that are important for estimating the potential risk to groundwater and surface water for protected crops. Water excess is the key to downward transport and if the soil under the greenhouse is drained, surface water contamination may also occur.

Emissions of plant protection products to **groundwater** can be estimated with FOCUS groundwater models, i.e. MACRO, PEARL, PELMO, PRZM, (FOCUS, 2000) if scenarios specific for indoor uses are available. Any of these models can be used to calculate leaching to groundwater from covered crops, provided that the irrigation water is distributed evenly over the crop and that other climatic

conditions are supplied as input to the model. For example, the PEARL model (Leistra *et al.*, 2001) with its integrated hydrological model SWAP (van Dam *et al.*, 1997) was used for this purpose (Beulke *et al.* 2011). PEARL is a mechanistic model that can calculate downward movement of water and PPP and entry into drainage systems. The movement of water through the soil is described based on the Richards equation and, recently, a macroporous flow module has been added (Tiktak *et al.*, 2011). Various groundwater regimes and drainage pathways into water courses can be simulated. Output from SWAP is read by the PPP model PEARL and the fate and transport of the plant protection product are calculated. The SWAP model can also be used to simulate water movement and balance in a covered structure for groundwater and surface water (drainage) simulations, although it was originally developed for open field uses.

Concentrations of PPPs in air within the covered structure can be greater than outdoors, due to higher temperatures and reduced dissipation. PPPs are thus likely to be carried to the outside air once they are present in the air within the system (EFSA, 2010c). Models exist for calculating **emission to air** and concentrations in air at short range distance from greenhouses. A modified version of PEARL was developed by Alterra and RIVM in order to improve the volatilisation concepts in PEARL (Van den Berg and Leistra, 2004). This version is now available as an option in FOCUSPEARL_v4.4.4 at the FOCUS website. Although the model has been developed to simulate volatilisation from the field, it can be used to estimate volatilisation from greenhouses if some assumptions are made. The FOCUS Working Group on Pesticides in Air (FOCUS, 2008) considers air as transport medium towards deposition onto soil and surface waters. Off-crop soil may be exposed via drift or via deposition of air-borne emissions

Water that exits the covered crop system can enter the soil, groundwater and surface water receptor compartments. Leaching models (FOCUS, 2000) can be used to simulate exposure concentrations in soil and groundwater. The models may also be used to calculate the emission to surface water via drainage, as is done for open field applications (see FOCUS, 2002). Drainage fluxes, and if applicable drift, can be used as input for TOXSWA (FOCUS, 2002) to calculate exposure concentrations in surface water.

Emissions from **soil-less cultivation systems** are not covered by the current risk assessment methodology for the field. A pilot model (no acronym available yet and therefore in this text referred to as Greenhouse Pesticide Fate Model (GPFM)) to simulate the fate of PPPs within soil-less systems has been developed and described (Vermeulen *et al.*, 2010). The model, which has three variants, assumes that the PPP is added to the mixing tank (variant 1), sprayed on a crop grown in a gully system (variant 2) or sprayed over a crop in an ebb/flow system (variant 3). Emissions of a PPP from soil-less cultivation systems to surface water can be simulated by the GPFM model if the output of total water supply, crop uptake, discharge and volumes of **condensation** from WATERSTROMEN model is used as input (Vermeulen *et al.*, 2010, Beulke *et al.*, 2011). GPFM simulates the release of the water and substance from the waste water tank into surface water based on a minimum level above which discharge starts and also based on a maximum allowed daily discharge into surface water. It also calculates leakage and filter rinsing. The output of GPFM includes the concentration of the substance within the system, and the percentages of the total compound in the system that is taken up by the crop, degraded and then enters the surface water. If the discharge fluxes are used as input in a surface water model, for example TOXSWA (FOCUS, 2002), resulting exposure concentrations in surface water can be simulated.

3. Simulation and interpretation of emission

EFSA (2010c) provided systems for categorising different types of protected structures (see also Table 1 and Appendix, section 3), application techniques and growing systems (EFSA, 2010c, Table 2). The categories are used here to further evaluate potential emissions and their relevancy (see section 3.1). This chapter considers two aspects for further evaluation: 1) emissions from covered crops in

299 comparison to emissions from equivalent open field situations (see section 3.2), 2) spatial aspects (see
300 section 3.3).

301 **Table 1:** Classification criteria and main categories of protection structures

	accessibility ^(a)	temporary structure	permeable cover ^(b)
low plastic tunnel	No	yes	no
high plastic shelter	Yes	yes	no
high net shelter	Yes	yes/no	yes (net)
shade house	Yes	yes/no	yes (net)
walk-in tunnel	Yes	yes	no
greenhouse	Yes	no	no

302 ^(a) accessibility for operators; ^(b) permeable to water

303 3.1 Relevant combinations

304 In the appendix (section 3) a large number of categories (respectively: 5 receptors, 6 construction
305 types, 5 application methods, 4 cultivation systems and 14 emission routes) are described, which can
306 be used to identify potential emissions from covered crops. From the potential 8400 combinations, a
307 number of combinations are not possible or only seldom occurs in reality. After elimination of these
308 non-occurring combinations, too many combinations still remain to consider them in detail. So, in
309 order to reduce the number of combinations, the Panel defined some rules and obtained a list of major
310 potential emission combinations for the receptors air, groundwater and surface water. Table 2 to Table
311 4 list the major potential emission combinations to the three receptors, resulting after application of the
312 rules described in the appendix (section 3). These combinations are further discussed in section 3.4.
313

314 **Table 2:** Major relevant combinations regarding emission to air

construction	system	application	type of emission [#]
greenhouse	soil no recirculation	spray	gas phase emission at application
greenhouse	soil no recirculation	spray	compulsory ventilation
greenhouse	soil no recirculation	spray	long term gas phase emission, uncontrolled
greenhouse	soil no recirculation	spray	long term gas phase emission, controlled
low tunnel	soil no recirculation	spray	gas phase emission at application
low tunnel	soil no recirculation	spray	long term gas phase emission, uncontrolled
net shelter	soil no recirculation	spray	gas phase emission at application
net shelter	soil no recirculation	spray	long term gas phase emission, uncontrolled
plastic shelter	soil no recirculation	spray	gas phase emission at application
plastic shelter	soil no recirculation	spray	long term gas phase emission, uncontrolled
shade house	soil no recirculation	spray	gas phase emission at application
shade house	soil no recirculation	spray	long term gas phase emission, uncontrolled
walk-in tunnel	soil no recirculation	spray	gas phase emission at application
walk-in tunnel	soil no recirculation	spray	long term gas phase emission, uncontrolled

315 [#] see Table B2 in appendix (section 3) for further explanation

316
317 **Table 3:** Major relevant combinations regarding emission to groundwater

construction	system	application	type of emission [#]
greenhouse	soil no recirculation	spray	leaching
low tunnel	soil no recirculation	spray	leaching
net shelter	soil no recirculation	spray	leaching
plastic shelter	soil no recirculation	spray	leaching
shade house	soil no recirculation	spray	leaching
walk-in tunnel	soil no recirculation	spray	leaching

318 [#] see Table B2 in appendix (section 3) for further explanation

Table 4: Major relevant combinations regarding emission to surface water

construction	system	application	type of emission
greenhouse	soil no recirculation	spray	drift
low tunnel	soil no recirculation	spray	drift
net shelter	soil no recirculation	spray	drift
plastic shelter	soil no recirculation	spray	drift
shade house	soil no recirculation	spray	drift
walk-in tunnel	soil no recirculation	spray	drift
greenhouse	soil no recirculation	spray	condensation
low tunnel	soil no recirculation	spray	condensation
net shelter	soil no recirculation	spray	condensation
plastic shelter	soil no recirculation	spray	condensation
shade house	soil no recirculation	spray	condensation
walk-in tunnel	soil no recirculation	spray	condensation
greenhouse	soil no recirculation	spray	gas phase emission at application
low tunnel	soil no recirculation	spray	gas phase emission at application
net shelter	soil no recirculation	spray	gas phase emission at application
plastic shelter	soil no recirculation	spray	gas phase emission at application
shade house	soil no recirculation	spray	gas phase emission at application
walk-in tunnel	soil no recirculation	spray	gas phase emission at application
greenhouse	soil no recirculation	spray	leaching
low tunnel	soil no recirculation	spray	leaching
net shelter	soil no recirculation	spray	leaching
plastic shelter	soil no recirculation	spray	leaching
shade house	soil no recirculation	spray	leaching
walk-in tunnel	soil no recirculation	spray	leaching
greenhouse	soilless with recirculation	drip irrigation	discharge
greenhouse	soilless without recirculation	drip irrigation	discharge
greenhouse	soilless without recirculation	spray	condensation (controlled)

[#] see Table B2 in appendix (section 3) for further explanation

3.2. Comparison of emissions

Commissioned by EFSA, Beulke *et al.* (2011) performed a number of simulations, using many of the models referred to in chapter 2, regarding emissions from covered crops to the environmental receptors air, groundwater and surface water and compared these emissions with emissions from equivalent open field systems. Their main findings were:

Emissions to air:

- Emission to air from greenhouse covered crop systems do occur; even from relatively closed systems such as low-tech and high-tech greenhouses. The driving force is the necessary ventilation of the system. Emissions were calculated for a high-tech greenhouse in the central zone as well as for a multispan greenhouse in the southern zone. Calculated emissions are up to 30% (90th percentile) of the applied dose for plastic and glass greenhouses.
- Calculated emissions from greenhouses, both high-tech greenhouses in the central zone and multispan greenhouses in the southern zone, are of the same order of magnitude for greenhouses and the open field. As it was not possible to use identical models for the calculation of the emissions, the results should be considered as indications and not as firm results.
- The main driving factor with regard to emissions of air-born substances is the need for ventilation, i.e. the need to keep inside climatic conditions favourable for crop growth.

Emissions to groundwater

- Leaching from a soil-bound cultivation in the central zone was shown to occur. From the results, it may be deduced that exceeding the threshold level for drinking water, 0.1 µg/l, may occur for specific substances.
- For comparable situations, except for the cover, leaching appeared to be lower for the covered crop in a greenhouse in comparison with the open field situation. The lower leaching level was attributed to the higher temperatures prevailing in the greenhouse.
- For other covered cropping systems, it is expected that differences between yearly average temperature of the covered cropping system and that of the open field in the same area will be lower than for the closed walk-in structures and therefore the difference in leaching will become smaller.
- The main driving factors with regard to emissions to groundwater are the temperature and the amount of water supplied, i.e. the amount of water in excess of the crops' requirements and the irrigation strategy.

Emissions to surface water

- Drift emission was calculated to occur for walk-in tunnels with ventilation openings in the cover. The order of magnitude from a single walk-in tunnel appeared to be the same as drift emission in the open field. The effect of multiple tunnels next to each other presumably has no additional drift loading on surfaces outside the borders of the premises.
- Emission of substances to surface water via drainage may occur when PPP are applied to soil-bound crops. The emission appears to depend highly on the timing of water supply after the application of the PPP. The same dependency was found for open field applications on soils with potential preferential flow of water.
- Condensation is a potential emission route that does not occur in open field applications. The amounts potentially emitted to surface water, when condensation is not collected, were calculated to be up to 12%. The most important driving factors appear to be temperature differences between inside and outside and substances properties related to volatilisation and distribution over air and water. Condensation may occur in both soil-bound and soil-less cultivations.
- Discharge of deteriorated nutrient solutions may be a source of PPP emission to surface water in soil-less cultivations. The emission is highly dependent on the moment of discharge in relation to the moment of application of the PPP. If the time span between application and discharge becomes larger, the emission becomes lower. Plant uptake was shown to have a major impact on lowering the emission. Equivalent situations do not occur in the open field.
- The main driving factor with regard to emissions to surface water in soil-less cultivation is the necessity to discharge deteriorated nutrient solution. The sodium level in the recirculating water may become critical for plant growth and this level is reached faster when available water is of poor quality (i.e. relatively high in sodium content). For soil-bound crops, the main driving force is the amount of supplied water, similar to the emission groundwater.

3.3. Spatial aspects

Table 2 to Table 4 list relevant protected cropping systems from which emissions may occur and which can be considered for further development of risk assessment methodology, including representative scenarios. From the tables, especially Table 3, it is obvious that all distinguished construction categories are still included. Whereas soil-less cultivation occurs in approximately 10%

of the area occupied by greenhouses (see appendix (section 3)), soil-bound cultivation is the dominant cropping system throughout all constructions. Section 4.2 list location (spatial) aspects for which information needs to be available in statistical databases and GIS in order to derive representative risk assessment scenarios.

At the moment, information on location (coordinates), size, lay-out, management, etc. is not readily available and can even be absent for small and more open cover constructions (see appendix (section 3)). In most European countries, information is not requested when regularly gathering statistical information, possibly because the small and more open constructions are temporary (for less than a growing season up to a few growing seasons).

The necessary information on location aspects is **partly available for greenhouses** (see also appendix (section 3) and the references stated there). For greenhouses, in most EU countries census information is available with respect to area covered, type of cover, crops grown and whether there is heating or not. Information on water sources (quantity and quality), greenhouse management, etc. needs to be gathered or estimated. Also, information on soils in greenhouses (for soil-bound cropping systems) needs to be available. Especially in areas with a longer tradition of greenhouse cultivations soils may have changed and available information in soil databases may not be representative of soils in greenhouses. Furthermore, information on drainage systems (when applicable) and the way surplus water is discharged (soil-less cultivations) is essential for estimating exposure concentrations in environmental receptors.

3.4. Conclusions from available information

The PPR Panel made an earlier recommendation (EFSA 2010c) not to develop risk assessment methodology for the receptor soil. So the receptor soil is not considered in this section.

3.4.1 Air

Calculations on emissions to air showed the emitted amounts from covered crops are of the same order of magnitude as emissions from open field cultivations. In theory, emissions are expected to be lower to marginally lower, dependent on the construction and, when relevant, climate control measures. Refreshment of air is expected to be higher in the open field while temperature is expected to be higher for most constructions. There are often management options to reduce the emissions from covered crops to air, for example via the timing of the application in relation to the requirement for ventilation (application just before sunset) and closing ventilation openings during and for some time after application.

Currently there is no protection goal set for the air compartment. Without a protection goal, it is impossible to develop appropriate risk assessment methodology, including derivation of representative emission scenarios. It is however necessary to take account of emissions to air when deriving methodologies for the receptors groundwater and surface water as emissions to air will influence the emissions to the other receptors and therewith the resulting concentrations.

The Holterman emission model and its modified version by Van Os *et al.* (1994) compute the concentration of PPP vapour in the greenhouse air by a set of differential equations that describe the processes of sedimentation, volatilisation, absorbance and ventilation as a function of time. In the model it is assumed that air, crop, soil and greenhouse cover all have the same temperature. The GPFM model (variants 2 and 3) also contains routines for calculating emissions to air, taking into account exchange of substances with the crop and soil, and thus accounts for losses to air when calculating emissions to surface water. Further evaluation of these models is necessary before selection of the most appropriate model can take place.

As emissions to air are expected to occur after application of plant protection products to covered crops, the Panel recommends assessing the potential for long range transport, via estimation and evaluation of the half-life of the substance in air, as is required for open field applications.

3.4.2 Groundwater

As shown in section 3.2, leaching to groundwater from soil-bound cultivations in greenhouses is possible. The major factors influencing the leaching were found to be the temperature in the greenhouse and the amount of irrigation in excess of the crop requirement, when soil characteristics were the same. It is expected that leaching from other constructions is also possible, depending on the two factors. Table 5 gives the estimated effects on leaching for the various constructions. For leaching, temperature and water supply over a longer period of time after application are important, when soil characteristics are the same.

Table 5: Potential effect of driving forces on leaching to ground water, as compared to the open field, under otherwise comparable conditions

construction	temperature [#]	water control [§]	potential effect
low plastic tunnel	+/-	-	no significant effect on leaching
plastic shelter	+/-	-	no significant effect on leaching
net shelter	+/-	-	no significant effect on leaching
shade house	+/-	-	no significant effect on leaching
walk-in tunnel	+	+	less leaching
greenhouse	+	+	less leaching

[#] +/- temperature is the same or only marginally different, + temperature is higher.

[§] - water supply is not controlled, + water supply is fully controlled

For the considerations summarised in Table 5, it is assumed that growers do not control water supply (rows 1 – 4) or do not excessively over-irrigate and not at too high irrigations rates (rows 5 and 6). Nowadays, nearly all growers in the Netherlands comply with over-irrigation of not more than 30% and an irrigation rate of not more than 20 mm per day (Wim Voogt, personal communication, June 2011). When deriving scenarios, however, such assumptions should be checked for all relevant areas and, when not met, actual practice should be taken into account. Higher irrigation rates could lead to ponding of the soil, with consequently higher leaching / drainage due to higher dispersion (FOCUS 2009).

Temperature has an influence on the transformation rate of the substance in soil. A one degree Celsius difference may change the transformation rate by approximately 10% under normal agricultural conditions. Low plastic tunnels are usually only there for a limited time. Shelters may affect the temperature in both a positive and negative direction. The overall effect is estimated to be negligible. In walk-in tunnels and greenhouses the temperature is expected to be higher.

Water supply to covered crops (low plastic tunnels, plastic shelters, net shelters and shade houses) is not usually different from water supply to crops in the open field, i.e. via precipitation. So for these constructions, no effect of water supply on leaching is expected. In contrast water supply is fully controlled in walk-in tunnels and greenhouses; the cover is not permeable to water. Amounts of water supply and timing can be based on the crop requirement and leaching can be controlled to some extent.

The overall effect of temperature and water supply on leaching is expected to be non-significant for low plastic tunnels, plastic shelters, net shelters and shade houses, while less leaching is expected for walk-in tunnels and greenhouses, i.e. compared to equivalent situations in open field cultivation.

The above reasoning is only applicable to systems with even water supply over the entire field / area. Uneven water supply, for example via drip irrigation or furrow irrigation, cannot be handled with models currently used in risk assessment. Such watering systems are used not only in covered crops, but in the open field as well. Leaching may be affected in both a positive (less leaching) and negative (more leaching) , depending on the way the PPP is applied. Leaching may be higher up to an order of magnitude (Leistra, 1985). In order to handle such a situation, model development is required.

The Panel is aware of the fact that characteristics of the soil in a construction may drift away from the original values and thus, after a long period of time, may substantially deviate. For example, because of the higher temperatures, soil organic matter may decrease. On the other hand, soil organic matter may increase because of the high manure applications. Changes in soil organic matter content may significantly influence the leaching process. It is expected that the deviations in soil characteristics will be absent or relatively small for low structures and more open walk-in structures. These structures usually have a temporary nature. On the other hand, soil characteristics may have changed considerably in greenhouses when they have been in place for decades.

As indicated in section 3.3 necessary information on location aspects is not readily available for the small and more open constructions. Gathering and organising this information will require quite some effort. As leaching is expected to be negligibly affected by these constructions, risk managers may consider not requiring leaching assessments specific for these constructions and include such covered crop systems when providing authorisation for open field applications. The Panel cannot recommend using open-field leaching assessments for such covered crop systems because the spatial distribution of the basic units (see section 4.1 for the definitions) for the low structures and more open walk-in structures is not identical to the distribution of the basic units for the same crop in the open field. Thus, probability density functions of the target value may differ significantly. Current FOCUS groundwater scenarios aim to provide 90th percentile concentrations considering all agricultural land within each of nine climatic zones (FOCUS, 2009). It is expected that the area of such covered crop systems is only a small fraction of the area of agricultural land in such a zone. Therefore the Panel considers it defensible to include such covered crop systems in the EU leaching assessments based on the FOCUS groundwater scenarios. Unfortunately, more specific underlying information on the spatial distribution of such covered crop systems is missing (see further chapter 4).

3.4.3 Surface water

If soil under a protective structure is drained, there is a possible emission of PPP to surface water via drainpipes. Before drainage can occur, the PPP must have leached to the level of the drain-pipes. For this emission route considerations concerning leaching apply (see section 3.4.2).

Run-off will not occur in walk-in tunnels and greenhouses and is not considered further in this section.

Contamination of surface water via condensation has no equivalent route in open field cultivations. If condensation occurs in greenhouses and is disposed of directly to surface water, this might lead to relatively high emissions to surface water (see section 3.2). The PPR Panel recommends collecting information on the disposal of condensation and to include this emission route in the risk assessment methodology when this route is not excluded by law. For other constructions, exposure of surface water via condensation is much less likely. If condensation occurs, it will drip on the soil covered by the construction and emission to surface water will only occur after passage of the soil. It is expected that the substance will undergo transformation processes and that the effect on exposure concentrations in surface water will be negligible.

Deposition on surface water because of drift and emission to the air are potential sources of PPP in surface water. Table 6 gives potential effects on exposure concentrations in surface water. PPP will not often be applied to low plastic tunnels when the cover is in place. During treatment the situation is then similar to open field. Small to negligible effects are expected on emission to air and drift for plastic shelters, net shelters and shade houses. Nets are known to have an effect on drift deposition on surface water, dependent on the mesh. Often mesh-size will be such that the effect can be considered

null. Drift deposition on surface water can also be lower for shade houses, depending on the structure of the side walls of the construction. Drift in walk-in tunnels may be (nearly) absent if the cover is continuous. As stated in section 3.2 drift emission is comparable to drift emission in open field when holes are present or side walls are rolled-up. Emissions to air from greenhouses can be reduced if ventilation is limited for some time. Drift emissions from greenhouses is negligible when openings are closed during application. A conservative approach is to assume that these short term emissions are not different from open field applications, although for greenhouses they are lower.

Table 6: Potential effects of drift and air-emission during application on exposure concentrations in surface water, relative to similar open field situation.

construction	air emission during application	drift	potential effect
low plastic tunnel	NA [#]	NA	negligible effect
plastic shelter	+/- ^{\$}	+/- [%]	negligible effect
net shelter	+/- to -	+/- to -	negligible effect - lower concentration
shade house	+/- to -	+/- to -	negligible effect - lower concentration
walk-in tunnel	+/- to -	+/- to -	negligible effect - lower concentration
greenhouse	+/- to -	-	lower concentration

[#] not applicable when cover is removed for application

^{\$} -, +/-, + lower, marginally different resp. higher air emission or drift

[%] considering the same application technique (downward / upward / sideways spraying)

Because emissions to the receptor air are of the same order of magnitude, it is unlikely that short-range atmospheric deposition is very different from atmospheric deposition after application to open field crops. The Panel recommends including atmospheric deposition in the assessment of surface water. As a first approximation, the methodology developed for open field (FOCUS 2008) can be applied.

For soil-less cultivations there are no equivalent situations in the open field. As reported in 3.2 emissions to surface water cannot be excluded and may lead to concentrations in surface water that are harmful to aquatic organisms. Therefore, the Panel recommends giving high priority to developing risk assessment methodology, including scenarios, for applications of plant protection products to soil-less cultivations. When developing this methodology, it may be checked whether risk mitigation measures are commonly available and applied, and thus can be included in the methodology.

From literature referenced in chapter 1 and section 3.2 it is obvious that there are many potential emissions to surface water, but not all emissions are equally important in terms of loadings of surface water and concentrations therein. In view of time constraints and resources, the Panel recommends performing scenario selection on the most important emission routes (the emission routes leading to the highest concentration in surface water) in combination with the mostly widely used application method and use the selected scenario also to calculate emissions for other combinations.

4. Considerations for scenario development for selected protected crop systems

4.1. Basic assumptions and starting points for deriving scenarios.

This paragraph gives descriptions of a number of basic elements relevant to scenario development for exposure assessments.

Basic unit

The basic unit (area) has been defined as an area having the size of a treated field (EFSA, 2011), having a typical size of 1 ha. This definition is adopted here, but with the understanding that it concerns a covered area. Within this area there may be variability, but this is not addressed specifically in the assessment.

Spatial population of basic units

Nowadays, it is common practice in Europe to use realistic worst case scenarios as the basis for risk assessment, as firstly applied for deriving leaching scenarios. The realistic worst case was then numerically translated to be the 90th percentile situation (FOCUS, 2000). This percentage, which is a risk management decision, has been used since then. So, to be able to perform a risk or exposure assessment, the population for which the target percentile situation is derived should be clearly defined. The currently accepted target percentile of 90% is used throughout this Opinion.

With regard to covered crops in the European Union, the following populations of covered crops can be distinguished (see also Figure 1):

1. All basic units in the entire European Union, together the entire area occupied by covered crops in the EU (blue area).
2. All basic units in a regulatory zone in the EU. Currently, three regulatory zones are distinguished (see for example EFSA (2010e) for a definition / map of the regulatory zones) (red area).
3. All basic units in a regulatory zone in the EU cropped to a specific crop or crop-group (yellow area).
4. All basic units in a regulatory zone in the EU cropped to a specific crop or crop-group, in a specific cultivation system under a specified cover construction type (green area) (see EFSA (2010c) for the description of the construction types)

Within population 4 (green area in figure 1) a further distinction could be made according to application type. The application type may have significant influence on the potential emissions. For example, more than an order of magnitude difference was found in emission to surface water between spray applications and applications with the nutrient solution (Vermeulen *et al.*, 2010).

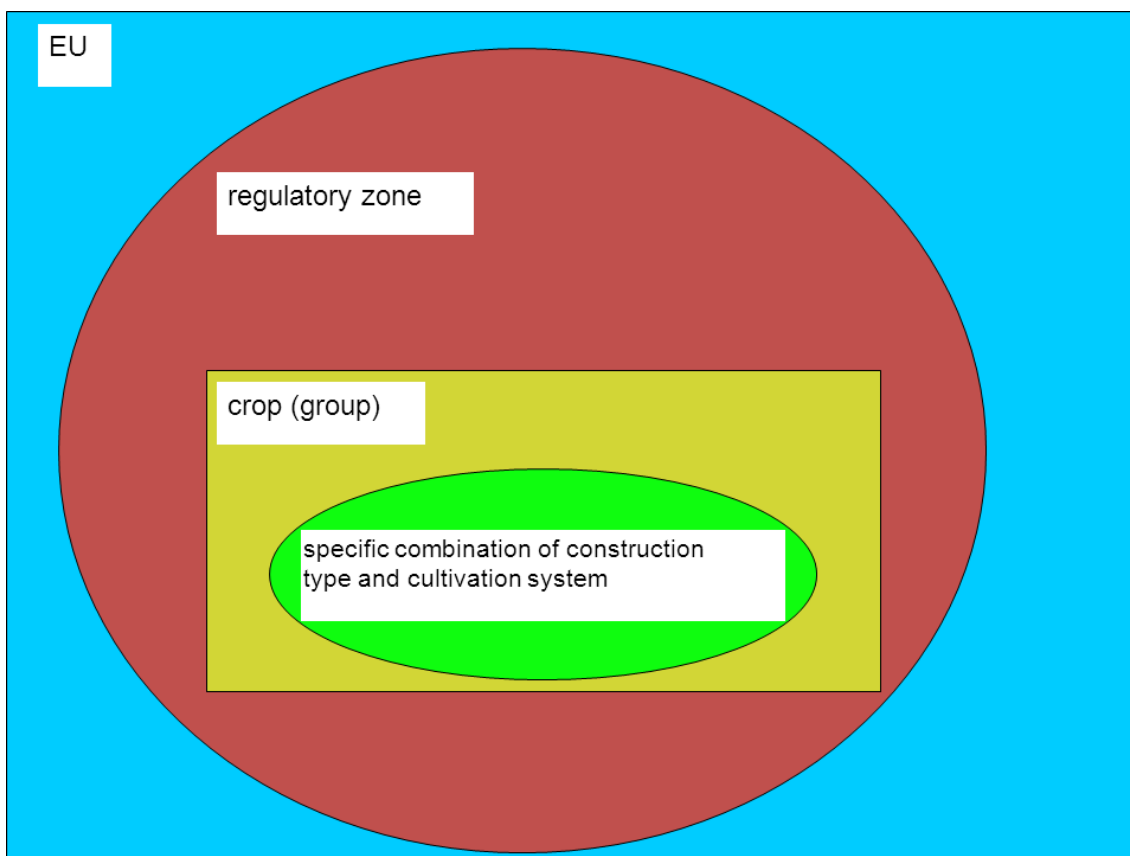


Figure 1: Schematic representation of the possible populations.

As shown in Figure 1, population 4 is a sub-population of population 3, which is a subpopulation of population 2, etc. The PPR Panel proposes using the population as defined under 4 (green oval in Figure 1) as the population for which a basic assessment should be performed, so the 90th percentile vulnerable situation for this population is used in the authorisation procedure. At the same time this means that more assessments should be performed when a crop is grown in several regulatory zones or under different types of construction in combination with application technique and cultivation system. An example of a population is: all basic units growing tomatoes on substrate in greenhouses in the central zone of the EU. It is recognised that, after an authorisation, potentially all basic units are potentially treated with the substance for which the risk assessment is performed. A further underlying assumption is that there is no bias if not all basic units are treated with the substance, i.e. the treated units are randomly distributed over the entire population.

As pointed out earlier (EFSA, 2010c; Stanghellini, 2009; Van der Linden, 2009), to a large extent climatic conditions prevailing outside a construction type determine climatic conditions and management practices inside the construction. Therefore the Panel recommends distinguishing between areas with a different climate.

Target to be used for scenario selection

As pointed out earlier, the target situation for the risk assessment is the 90th percentile situation in the population under consideration. The 90th percentile situation is then usually taken as the 90th percentile exposure concentration in the receptor. At the moment, the receptors (especially air and surface water) are not defined in terms of dimension and location where the exposure concentration has to be determined. For groundwater, the same approach as for open fields could be adopted, i.e. take the

607 annual averaged, flux weighted concentration at the boundary level (1 m below soil surface) as the
608 target exposure concentration. For air and surface water another approach has to be adopted.

609 For surface water and air it is too early to decide on the target. It is, however, assumed that emissions
610 from the covered crop system are highly related to the concentrations in the receiving receptor and that
611 emissions can therefore be used as an approximation to the concentrations. This will be especially true
612 on a relative scale, i.e. when situations are compared relative to each other.

Targets for scenario selection (proposal):

Air

Peak of daily emissions to air (during a growing cycle), considering both short-term and long-term emission processes.

Surface water

Peak of daily emissions to surface water. Contributions to the daily emissions may be different for different construction types and growing systems. For example: drift and drainage for more open constructions, discharge of recirculation water for substrate cultivations in greenhouses.

Groundwater

Annual average leaching concentration at 1 m depth.

Considerations

Leaching to groundwater is a long-term process while emissions to air and surface water, as well as the processes in those receptors, are much more variable in time. Simulations with soil exposure scenarios, selected on the peak concentration, showed that the scenarios were protective for time weighted average concentrations as well (EFSA, 2011).

613

614 Protection goal

615 Throughout this opinion, it is assumed that the exposure assessment goals as set for groundwater and
616 surface water and used in risk assessment for the open field apply to risk assessment for covered crops
617 as well. There is no reason to use different protection goals. A protection goal for the air compartment
618 still has to be defined by risk managers.

619 **4.2. Principles of scenario selection**

620 As a consequence of the missing protection goal for the receptor air, it is considered not useful to
621 address scenario selection and development for this compartment at this moment.

622 Principles of scenario selection are outlined elsewhere (FOCUS 2000, 2001, 2008, EFSA, 2010e).
623 These principles / concepts were applied earlier for selecting leaching scenarios for open field
624 applications and exposure concentrations in the top layers of agricultural fields. The concepts include
625 the following aspects:

- 626 • A model for calculating the target quantity is a prerequisite. Without a model it is not possible
627 to derive target scenarios. For scenario selection, sometimes metamodels (derived, simplified
628 models) may be appropriate.

- Variation in concentrations due to time aspects: weather conditions vary in time and, as a result, emissions and concentrations in the receptor may vary in time.
- Variation in concentrations due to spatial variation: soils at different location have different characteristics and, as a result, the interaction with plant protection products differ and will result in different leaching and drainage concentrations.
- Variation due to differences in substance properties.
- Uncertainty in driving processes due to uncertainty in soil characteristics and substance parameters.

The procedure is that a (large) number of runs with the model are done and that the results are plotted in a (contour) diagram. Calculations are performed for all basic units (or an approximation thereof) for a long term period (for example 20 years) and a number of substances with varying fate (a.o. transformation and sorption) properties. The results are sorted (low to high) for individual units (time aspect) and subsequently sorted (low to high) over the individual units (spatial aspect). A 2D plot of the sorted results (after conversion to a relative scale, 0 – 100%, for both the temporal and spatial aspects) will show (by approximation) lines of equal concentrations and the total appears as a contour plot (see Figure 2). The target scenario can now be derived from the contour plot. For example, if the target is the 90th percentile concentration then all combinations (space and time) with a result concentration on the 90% contour may be selected as the target scenario (solid white line in Figure 2). A further selection may be based on risk management arguments. If risk managers consider spatial and temporal aspects equally important, a scenario with equal %-values on horizontal and vertical axes (dashed lines at 80% in Figure 2) should be selected. If risk managers consider temporal aspects more important than spatial aspects, then a higher percentage should be selected at the vertical axis and, consequently, a lower percentage at the horizontal axis. An example of the latter case is indicated by the dashed lines crossing at 60% resp. 95%; this combination also leads to an overall 90th percentile combination. As a numerical example, let us assume that 20 basic units are considered and that for each of them 20 peak concentrations are calculated (one for each year). In total there are then 400 peak concentrations. The 90th percentile contour line ranks 360 results below and 40 results above the line. Now there still is a choice whether two units may have higher concentrations all the time (one extreme), twenty units may have higher concentrations in two out of 20 years (other extreme), or any other combination in between the two extremes. The decision is not necessarily the same for all protection goals and may depend on (eco)toxicological and other considerations.

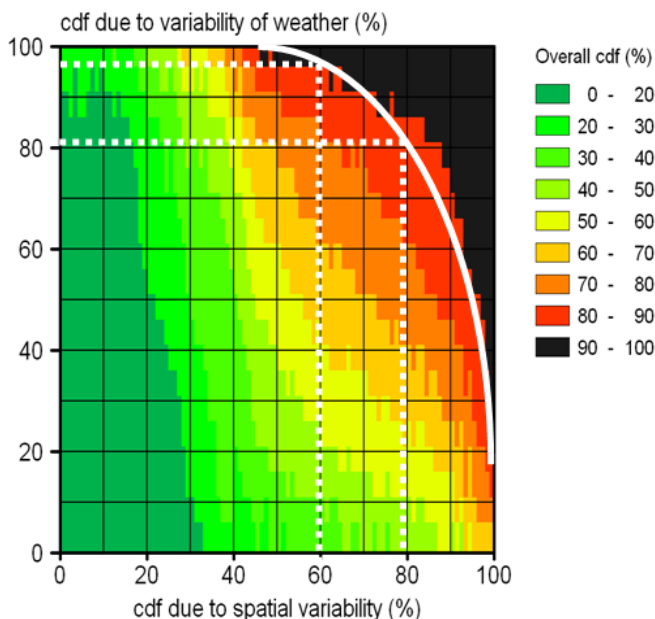


Figure 2: Example of a contour plot (taken from Tiktak *et al.*, 2011). See text for further explanation

A contour plot has to be established for each of the populations for which scenario selection is considered necessary. If the approach described above is followed, then the vertical axis is used to denote time aspects. For all covered crop systems, variability due to time is caused by variability in weather conditions over a period of time. As indicated in chapter 3, outside climatic conditions influence inside climatic conditions to a large extent and therewith the emission processes. Databases on climatic conditions in Europe exist (see for example EFSA 2010e), but possibly need to be refined from daily to hourly resolution (see chapter 3). In this respect, temperature management (set-points for inside climate control) also needs to be available, estimated or gathered.

The horizontal axis is used to take spatial or location aspects into account. Which aspects need to be taken into account may differ according to the population for which the scenario selection has to be performed. For soil-bound cultivations, the following aspects need to be considered and therefore information on these aspects needs to be available or gathered for all units in the population:

- Soil properties e.g. soil texture, bulk density, organic matter content, pH (including pH-measurement method);
- groundwater level including bottom boundary condition;
- Level of drainpipes (when applicable);
- Irrigation type (dripping, sprinkler, soaking, misting etc), regime and system (closed with recirculation versus open);
- Water supply strategy (excess level);
- Representative crop growth parameters for the crop or crop group under consideration).

For soil-less cultivations, the spatial aspects to be taken into account differ considerably:

- Management and quality of the different water sources, including size of water basins (see Vermeulen *et al.* 2010 for more detail);
- Strategy with respect to water supply to the crop (the so-called drain fraction or ratio of fresh: recirculation water);
- Collection and use of condensation (when applicable);
- Discharge strategy;
- Climate (Temperature, moisture);
- Disinfection and filtering of (recirculating) water.

4.3. Concluding remarks with respect to scenario selection and development

The main aspects to be taken into account when selecting scenarios are listed in the previous section. Information on the aspects will often not be available. If information is available, it should be checked that the information includes the covered crops or can be regarded as representative for the situation in covered crops.

Ranges in parameter values acceptable for assessments regarding open field are not necessarily valid for covered crops. Allowable ranges should be carefully checked.

Although several modelling tools can be used to estimate PPP emissions from protected crops to different environmental compartments, most of these tools were originally developed for open field simulations. Consequently, a number of assumptions and simplifications are typically made in order to expand the applicability of the modelling tools to indoor conditions and this can be the cause of large uncertainty.

Protected crops are often irrigated and irrigation over and above the crop's requirements is common. The excess water and associated PPP may reach groundwater and/or surface water. However the modelling tools that can be used to simulate the water balance in a covered structure either use simplified irrigation models (e.g. SWAP that does not consider drip irrigation) or have primarily been developed for soil-less systems (WATERSTROMEN model). The models should be used with care when used for protected crops.

Drip and other non-homogeneous water supply cannot be handled with models currently used in risk assessment. As these types of irrigation are important in covered crops and are becoming more and more important in the open field, the Panel recommends developing a model capable of handling such irrigation types.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Major conclusions

The Panel concludes that emissions from covered crops to the environmental receptors air, groundwater and surface water do occur and that these cannot be ignored when evaluating the authorisation of PPP. Emissions to groundwater and surface water are expected to be influenced significantly for greenhouses and walk-in tunnels. For other covered cropping systems influences are expected, but these are probably insignificant in view of the authorisation process. The Panel therefore proposes giving priority to developing scenarios for the following limited set of structure/application/receptor combinations. With limited resources, the Panel recommends focusing on the major emission routes when selecting the scenarios and generally using these scenarios for all emissions.

construction	system	application	emission	receptor
greenhouse	soil no recirculation	spray	leaching/drainage condensation gas phase emission at application	groundwater surface water
walk-in tunnel	soil no recirculation	spray	gas phase emission at application drift leaching/drainage	groundwater surface water
greenhouse	soilless with recirculation	drip irrigation spray	discharge	surface water
greenhouse	soilless without recirculation	drip irrigation spray	discharge condensation	surface water

Soil-less cultivation has no equivalent in the open field. Scenarios need to be developed for these growing systems. Discharge from these systems may be higher than any emission from the open field to surface water. Also condensation is a potential emission route in protected crop systems, for which there is no equivalent route in open field systems. If the condensation is collected and reused as a water source in soil-bound cultivation, there will be no significant additional emission to surface water or groundwater. If the collected condensation is not reused or the condensation flows directly to surface water, the emission of PPP might be significant. The currently used emission percentage seems to undervalue the emission and needs to be reconsidered.

Other conclusions

The classification systems for structuring the covered crops sector (EFSA 2010c) proved useful for identifying and ranking emissions of PPP from covered crops.

It is unlikely that, taking equivalent application techniques into account, drift emissions from protected crop systems are very different from drift emissions from open field situations, when the side walls of the structure are absent or not fully closed.

Leaching from greenhouse systems to groundwater appeared to be smaller than from open field, when conditions were similar and differences only induced by the cover. The major reason for the different (smaller) leaching was found to be the temperature in the greenhouse; the average annual temperature in the greenhouse in the calculations was higher. It is expected that differences will become smaller when temperatures are closer to each other. It is expected that the average annual temperature for the covered crop situation will not be less than that for the open field situation. The conclusions drawn for

leaching after application to soil-bound crops can be extrapolated to drainage to surface water. An open field scenario may perhaps serve as a first tier for the risk assessment, while for higher tier assessment specific scenarios are necessary. Whether open field assessment can be used as a first tier requires an analysis of relevant leaching probability density functions and comparison of these functions with similar functions for open field leaching.

Drip irrigation is important in soil bound cultivations for protected crop systems. When this irrigation system is used, emissions to groundwater may be higher as well as lower when compared to normal irrigation or precipitation. As a first approach, an irrigation correction factor of 10 (a factor of 10 more leaching than for evenly distributed irrigation) can be applied, based on extrapolation from Leistra (1985). Application with the nutrient solution in soil-less cultivations may lead to higher emissions to surface water as compared to other application types. This should be accounted for in the authorisation procedure.

If an outdoor assessment for a substance on persistence in soil has been performed and an acceptable risk has been shown, there is no reason not to accept this conclusion for soil in greenhouses, for the same climatic or regulatory zone. In many cases soils in greenhouses (soil-bound cultivation) can hardly be considered similar to field soils; they could be regarded more similar to substrates.

5.2. Recommendations

Major recommendations

It is recommended that risk managers should not allow authorisation of PPPs specifically for low structures (low tunnels), plastic shelters, net shelters and shade houses as emissions from these systems are expected to not differ significantly from those in open field. This recommendation implies that regulatory decisions should be based on the combined applications of PPPs in the open field and in the corresponding covered crop system. This avoids the need for the time-consuming development of specific scenarios for the covered crop systems. In addition, statistical information on these systems is largely lacking and scenario development for these systems would only be possible at the expense of high costs.

At the moment, there is no protection goal set for the air compartment. As emissions to the air compartment do occur from all covered crop systems, the Panel recommends that risk managers consider setting a protection goal for the air compartment. Without a protection goal, it is impossible to develop risk assessment scenarios. In view of the necessity for a protection goal and evaluation scenarios, the Panel recommends applying all air compartment criteria for open field applications to all applications for PPP use in protected crops. As an example, the Panel recommends always assessing the half-life of a substance in air for long range transport as is currently done for the open field.

The Panel recommends that methodology for environmental exposure assessment is developed for all environmental receptors and that, when doing this, variability in space and time is taken into account. In order to limit the number of scenarios (a large number would render an impractical and inefficient authorisation procedure), the Panel recommends focusing on major emission routes when developing scenarios and including minor emission routes in these scenarios. Likewise, the Panel recommends focusing scenario development on the most important application techniques (mostly spraying).

It is recommended that a future working group evaluates whether current risk assessment methodology for the open field for the receptors groundwater and surface water may serve as a first tier in the evaluation of substances intended to be used in covered crops. For example, as leaching from soil-bound cultivation in greenhouses is expected to be lower than in the open field, the leaching assessment for the open field could possibly become a first tier in the leaching assessment for greenhouse applications.

797

798 Specific recommendations

799 Currently there is no generally accepted model for calculating emissions to air. As emissions to air
800 will have influence on exposure concentrations in the environmental receptor groundwater and surface
801 water, it is recommended to develop an appropriate model for calculating/simulating emissions to air.

802 The models currently used in risk assessment for calculating leaching and drainage cannot be used (or
803 only with high uncertainty) when water supply to the crop is not uniform (not evenly distributed). This
804 is also important in the open field, as drip irrigation is becoming more and more important. The Panel
805 recommends developing an appropriate model for this situation.

806 If scenarios for open field leaching, i.e. the FOCUS groundwater scenarios, are considered as a first
807 tier in leaching assessments for applications in closed walk-in systems, it may be necessary to amend
808 these scenarios with crops specifically grown in these structures or, at least, link typical covered crops
809 to crops available in the scenarios.

810

REFERENCES

- Bezemer J, Voogt W, 2008. Elke kuub water van bron tot sloot in beeld gebracht (interview met Wim Voogt) - Met nieuw rekenmodel kan teler zijn watermanagement optimaliseren. *Onder Glas* 5 (2). p. 46 - 47. (in Dutch)
- De Graaf R, 1988. Automation of the water supply of glasshouse crops by means of calculating the transpiration and measuring the amount of drainage water. *Acta Hort.* 229, 219-231.
- De Zwart HF, 1996. Analyzing energy-saving options in greenhouse cultivation using a simulation model. PhD dissertation, Wageningen University, 236 pp. ISBN 90-5485-533-9.
- EFSA, 2010a. European Food Safety Authority; Report on the PPR stakeholder workshop PROTEA on pesticide emissions from protected crop systems. *EFSA Journal* 2010; 8 (2):1509. [31 pp]. doi:10.2903/j.efsa.2010.1509. Available online: www.efsa.europa.eu
- EFSA, 2010b. European Food Safety Authority; Data Collection of Existing Data on Protected Crop Systems in the European Member States - Coding Manual. *EFSA Journal* 2010; 8(3):1568 [81 pp.]
- EFSA, 2010c. Panel on Plant Protection Products and their Residues (PPR). Scientific Opinion on emissions of plant protection products from greenhouses and crops grown under cover: outline for a new guidance. *EFSA Journal* 2010; 8(4):1567. [44 pp]. doi:10.2903/j.efsa.2010.1567. Available online: www.efsa.europa.eu
- EFSA, 2010d. European Food Safety Authority; Modelling approach to estimate emission of Plant Protection Products from protected cropping systems to surface water in Mediterranean countries. *EFSA Journal* 2010; 8(8):1615. [18 pp]. doi:10.2903/j.efsa.2010.1615. Available online: www.efsa.europa.eu
- EFSA, 2010e. Selection of scenarios for exposure of soil organisms to plant protection products. *EFSA Journal* 2010; 8(6): 1642, [82 pp]. doi:10.2903/j.efsa.2010.1642. Available online: www.efsa.europa.eu
- EFSA, 2011. Scientific Opinion on guidance for assessment of exposure of organisms to substances in soil. (in prep, open for public consultation, www.efsa.europa.eu)
- Sas Paszt L, 2010f. Data-collection of existing data on protected crop systems (greenhouses and crops grown under cover) in Eastern European Member States in EU. The Research Institute of Pomology and Floriculture, Poland, 47 pp Question number: EFSA-Q-2008-05004 <http://www.efsa.europa.eu/en/supporting/doc/32e.pdf>
- Sigrimis N, Cavallini A, Incrocci I, Montero J I, Parra J P and Kafka A, 2010g. Data-collection of existing data on protected crop systems (greenhouses and crops grown under cover) in southern European Member States in EU. University of Athens, Greece, 192 pp. Question number: EFSA-Q-2008-05003. <http://www.efsa.europa.eu/en/supporting/doc/31e.pdf>
- Saunders N, 2010h. Collection and Evaluation of relevant information for the development of a new Guidance document on Emissions of Plant Protection Product from Protected Crops (e.g. greenhouses and crops grown under cover) – data collection for four study regions in the central zone as defined in the draft regulation on “Placing Protection Products on the Market”. Campden BRI, UK, 167 pp. Question number: EFSA-Q-2009-01086. <http://www.efsa.europa.eu/en/supporting/doc/76e.pdf>
- Montanari S, Minuto A, Tinivella F, Minuto G and Delfino G, 2011. Collection and Evaluation of relevant information for the development of a new Guidance document on Emissions of Plant Protection Product from Protected Crops (e.g. greenhouses and crops grown under cover) – data collection for four study regions in the southern zone as defined in the draft regulation on “Placing Protection Products on the Market”. Centro di Sperimentazione ed Assistenza Agricola, Savona, Italy. 147 pp. EFSA-Q-2010-01467. <http://www.efsa.europa.eu/en/supporting/doc/106e.pdf>

- Beulke S, van Beinum W, Glass R, van Os E, Hoterman H J, Sapounas A, Voogt W, van de Zande J, de Zwart F and Garratt J, 2011. Estimation/calculation of emissions of Plant Protection Products from protected crops greenhouses and cultivations grown under cover) to support the Development of risk assessment methodology under Council Directive 91/414/EEC and EU regulation 1107/2009 (EC). Consortium. 126 pp, EFSA-Q-2010-00830. <http://www.efsa.europa.eu/en/supporting/pub/151e.htm>
- FOCUS, 2000. "FOCUS groundwater scenarios in the EU review of active substances" Report of the FOCUS Groundwater Scenarios Workgroup, EC Document Reference SANCO/321/2000 rev.2, 202pp.
- 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.
- Hemming S, van Henten E, van 't Ooster B, Vanthoor B, 2007. Systematic design of greenhouse crop production systems. Edepot.wur.nl/31376
- Leistra M, 1985. Computer simulations of the transport of pesticides with nonuniform water flow in greenhouse soil. Soil Science 140: 161 -169.
- Leistra M, van der Linden AMA, Boesten JJTI, Tiktak A, van den Berg F, 2001. PEARL model for pesticide behaviour and emissions in soil-plant system: Description of the processes in FOCUS PEARL v 1.1.1. Bilthoven, National Institute for Public Health and the Environment, RIVM report 711401009. Wageningen, Alterra, report 013. 116 pp.
- Rath T, 1992. Einsatz wissensbasierter Systeme zur Modellierung und Darstellung von gartenbautechnischem Fachwissen am Beispiel des hybriden Expertensystems HORTEX, Hannover.
- Rath T, 2006. HORTEX 3.0 and HORTEXlight 1.0 - Graphical software systems for the calculation of the energy demand of greenhouses.
- Stanghellini C, 2009. Emissions by aerial routes from protected crop systems (greenhouses and crops grown under cover): a position paper. Wageningen UR Greenhouse Horticulture, Report 224: 21 pp. <http://www.efsa.europa.eu/en/supporting/pub/10e.htm>
- Tchamitchian M, Martin-Clouaire R, Lagier J, Jeannequin B, Mercier S, 2006. SERRISTE: A daily set point determination software for glasshouse tomato production. Computers and Electronics in Agriculture, 50 (1):25-47
- Teunissen RJM. 2005. Emissies van gewasbeschermingsmiddelen uit de glastuinbouw [Emissions of plant protection products from glasshouses]. Riza rapport 2005.019, Riza, Lelystad, 69 pp. (in Dutch)
- Tiktak A, Adriaanse PI, Boesten JJTI, Delsman J, Griethuysen C van, Horst MMS ter, Linders JBHJ, Linden AMA van der, Zande JC van de. 2011. Scenarios for exposure of water organisms in the Netherlands. Edge of field water courses. RIVM Report 607407002/2011. In prep.
- Van der Linden AMA, 2009. Emissions by "other routes than air" from protected crop systems. Technical report to EFSA under procurement NP/EFSA/PPR/2008/04. <http://www.efsa.europa.eu/en/supporting/pub/10e.htm>
- Van Dam JC, Huygen J, Wesseling JG, Feddes RA, Kabat P, van Walsum PEV, Groenendijk P, van Diepen CA, 1997. SWAP version 2.0. Theory. Simulation of water flow, solute transport and plant growth in the Soil-Water-Atmosphere-Plant environment. Report 71. Department of Water Resources, Wageningen Agricultural University, Technical Document 45. DLO Winand Staring Centre, Wageningen.

- 905 Van den Berg F, Leistra M, 2004. Improvement of the model concept for volatilization of pesticides
906 from soil and plant surfaces in PEARL. Description and user's guide for PEARL 2.1.1-C1.
907 Available at www.pesticidemodel.eu: FOCUS AIR PEARL.pdf
- 908 Van Os EA, Holterman HJ, and Klomp G, 1994. Management of emission flows of pesticides from
909 glasshouses. Acta Horticulturae (ISHS) 372, 135-141
- 910 Vermeulen T, van der Linden AMA, van Os EA (eds), 2010. Emissions of plant protection products
911 from glasshouses to surface water in The Netherlands. WUR Greenhouse Horticulture report GTB-
912 1002, RIVM report 607407001.
- 913 Voogt W, Kipp JA, de Graaf R, Spaans L, 2000. A fertigation model for glasshouse crops grown in
914 soil. Acta Hort, 537, ISHS 2000, 495-502.
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917 **GLOSSARY AND ABBREVIATIONS**

2D	two dimensional
cdf	cumulative (probability) density function
EC	European Community
EEC	European Economic Community
EFSA	European Food Safety Authority
emission	technical term signifying the transfer of a substance over a boundary
ERA	Environmental Risk Assessment
EU	European Union
FOCUS	FORum for the Co-ordination of pesticide fate models and their USE
GIS	Geographical Information System
GPfM	Greenhouse Pesticide Fate Mode
GW	groundwater
MACRO	leaching model, specifically developed for addressing macroporous water flow in soils
MS	member state of the European community
PEARL	Pesticide Emission At Regional and Local Scale. Model for calculating fate and behaviour of substances in soil
PEC	Predicted Environmental Concentration
PECair	PEC in air
PECsoil	PEC in soil
PECsw	PEC in surface water
PELMO	PEsticide Leaching MOdel. Model for calculating fate and behaviour of substances in the soil
PPP	plant protection product
PPR	Panel on Plant Protection Products and their Residues
protection	The word „protection“ is often used to refer to physical barriers (i.e. plastic, glass or netting) or to refer to chemical / biological products that are applied to the crop (e.g. pesticides or plant growth regulators). Since this term could be ambiguous, we have chosen to use the term „PPP“ to refer to products (Plant Protection Products). When the word „protection“ or „protected“ appears, it refers to the physical barriers.
PRZM	Pesticide Root Zone Model. Model for calculating fate and behaviour of substances in the unsaturated zone of the soil
receptor	For the purpose of this opinion, a receptor is an environmental compartment receiving emissions, such as surface water, air, soil and groundwater.
SE	South East
solids	For the purpose of this opinion, solids are defined as solid materials such as plastic covers, plant residues, soil and substrate that can be removed from the protected structure.
substrate	any material, not in connection with subsoil, used for growing plants on
SWAP	Soil Water Atmosphere Plant model. Model for calculating water and heath transport in soil.
TOXSWA	TOXic substances in Surface WAters. Model for calculating fate and behaviour of substances in water courses
WG	Working Group

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920 APPENDIX:

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925 **TECHNICAL BACKGROUND INFORMATION**

926 **Potential emission routes of plant protection products from greenhouses**
927 **and crops grown under cover**

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1. Introduction

EFSA (2010) gives definitions of structures, cultivation systems and application techniques that are used in the cultivation of protected crops. Appendix A lists these definitions as well as their abbreviations for easy reference. Stanghellini (2009) and Van der Linden (2009) give the potential emission routes of plant protection products (PPP) associated with the cultivations. Emission here is defined as the transfer to the outside of a substance over a real or imaginary boundary and is usually presented as a percentage of the applied dose. It is recognised that not all combinations of construction type, cultivation system, application technique and emission route are possible. This report identifies the combinations that are possible. The report serves as a background report to the further development of guidance and scenarios for risk assessment.

The foreseen guidance will identify applications of PPPs to protected crops for which emissions are considered not different from open field applications and furthermore give some details on the development of emission and exposure scenarios for applications which might lead to different emissions.

Chapter 2 of the report provides an overview of protected crop cultivation in Europe in terms of acreages, with differentiation over structures and cultivation systems as far as available. The most important crops are included in this chapter as well. Chapter 3 identifies all combinations of structure, application technique and growing system with potential emissions from covered crops to environmental receptor and Chapter 4 discusses possibilities of combining these potential emissions to further reduce the number to be taken into account in scenario development. Finally, Chapter 5 gives conclusions on combinations to be taken into account for scenario development and recommendations on further data collection and model development.

It is recognised that, at least in some covered crop systems, biocides may be used. This report deals with emissions resulting from applications of PPPs and therefore emissions resulting from the use of biocides is not covered. For example, cleaning a soilless system with a biocide in absence of a crop will not be covered by an emission scenario in which a PPP is applied to the crop. It must also be noted that the text does not cover PPPs with an active substance based solely on micro-organisms.

2. Overview of covered crop cultivations in the EU

Acreage, location, management, etc., are important aspects that have to be taken into account when deriving scenarios for risk assessment. This chapter summarises European data on these aspects. More details are given in Appendix C and references.

2.1. Data collection

Acreages with crop protection structures are rarely reported and mostly reported at national level. Different definitions on structures, different classification of crops and different measurements of the covered area are used. For this reason EFSA started in 2008 an initiative to harmonise and collect the scattered information. As a first step, protection structures were classified into 13 categories (figure 2.0, EFSA, 2010). Census data is usually available only for the large walk-in structures. The absence of such data for smaller structures is probably because of the temporary nature of such structures.

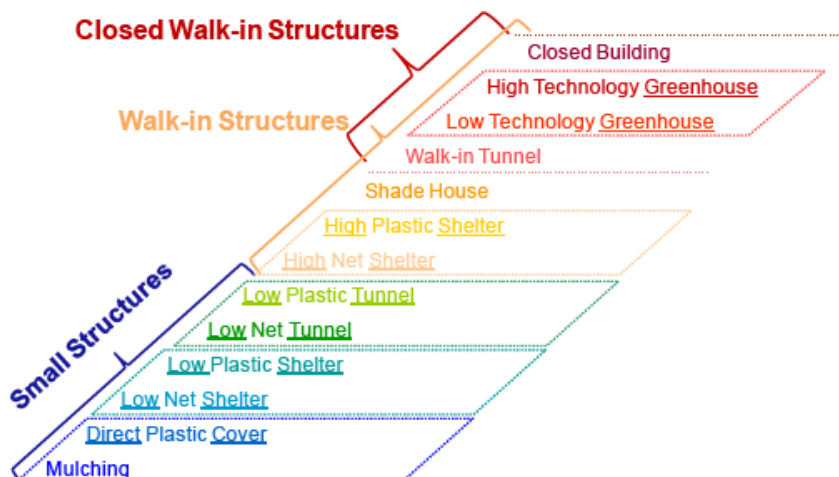


Figure 2.0: Classification of protection structures (EFSA, 2010)

A hierarchical approach is also used to classify the protected crops. Main groups are: fruits; leafy, fruity and other vegetables; cut flowers, pot ornamentals and propagation materials.

2.1.1. Collection of existing data in Eastern Europe

For Eastern European Member States existing data on protected crop systems were collected by the Research Institute of Pomology and Floriculture (RIPF) in Skierniewice (Poland) in the first half of 2009 (Sas Paszt, 2010). Information was gathered from the national statistical offices and governmental authorities by written request and through access to their websites. Some data gaps were identified and additional contacts were made to research institutes and growers associations to obtain missing information.

In general, information on protected crops is sparse in Eastern Europe. Main data are given only on the national level for the area covered by large and/or permanent structures, like greenhouses or walk-in tunnels. Characteristics of the growing systems or practices are widely missing.

2.1.2. Collection of existing data in Southern Europe

In the first half of 2009 data on protected crop systems were also collected for Southern European countries by N. Sigrimis (coordinator) of the Agricultural University of Athens (Sigrimis *et al.*, 2010). The project evidenced major problems in gathering information from the national statistical institutes and governmental authorities. Therefore information was obtained by contacting research institutes and reviewing published literature.

Detailed regional results were found for Greece, Italy and Cyprus, but only limited information on the characteristics of the structures and growing techniques could be identified.

2.1.3. Collection of existing data in Northern and Central Europe

The Northern and Central European countries were assessed via a web search on the sites of the national statistical offices (EFSA 2011, in prep.). Relevant surveys were identified and most recent reports were used to extract the data. Data gaps were filled by direct access to the public databases or, if not available, by data from EUROSTAT.

There is a varying degree of detail between the countries. Except for Ireland and Luxembourg information on crops under protective structures was available at national level for the main crops for all countries. Most countries also provided information on a regional level. The main structures

mentioned are closed walk-in structures, sometimes specified by some characteristics (coverage, isolation, heating etc.) as walk-in tunnels, low or high technology greenhouses.

2.1.4. Filling data gaps by additional sampling

Along with area and geographical distribution of protected crops, developing scenarios for investigating potential emission routes of PPPs from protected crops requires the collection of data about a number of technical elements such as: how temperature and ventilation are controlled; the use of pest blocks/screens; soil type; irrigation technique; approach to irrigation scheduling (how crop water requirements are estimated); quality/source of irrigation water; the application of open or closed soilless growing systems; growing season for the most important crops and the possible application of multi-crop production schemes (e.g., year-round production of leafy vegetables or cut flowers such as chrysanthemums); methods and frequency of PPP applications.

The aforementioned procurement reports published in 2010 (Sas Paszt, 2010; Sigrimis *et al*, 2010) provide very few data in this regard. For instance, some information is reported on the application of soilless cultures in Poland, France and Spain (Almeria) and on ventilation systems and the use of insect screens in Spain (Almeria), but is absent for other areas.

The survey conducted by Campden BRI (Saunders, 2010) used a web-based questionnaire to gather technical information on greenhouse structures and management in four selected countries in Northern Europe: The Netherlands, United Kingdom, Poland and Hungary. Unfortunately, only 83 questionnaires were collected, mostly from The Netherlands and United Kingdom (only four from Hungary). Therefore, the conclusions are not certain due to the small size of data set, in spite of the large diffusion of high-technology greenhouses.

The study performed by Centro Sperimentazione Assistenza Agricola in Albenga (Italy) (Montanari *et al.*, 2011) is much more exhaustive. This survey considered on-site interviews with growers and consultants in different greenhouse areas in France, Italy, Greece and Spain. In total, 523 questionnaires were collected: 146 in North-Western Italy, 164 in Sicily, 32 in France, 98 in Spain and 83 in Greece. Many data about climate and crop management, including the application of PPPs, are reported for the most important greenhouse areas ('hot spots') in the Mediterranean area such as those around Ragusa in Italy, Ierapetra in Crete, and Almeria in Spain.

Data are not available for either northern countries or for soil type in any of the considered regions, although the latter information can be gathered from current literature (for instance, soil-like 'enarenado' in Almeria greenhouses is illustrated in many scientific papers; Gonzales-Prada *et al.*, Soil Sci. Soc. Am. J. 2002) and from the European Soil Data Centre (ESDAC).

2.2. Areas with covered crops and their distribution over Europe

The available data are rather sparse and mostly pertains to large and/or permanent crop protection structures, namely "Closed Walk-In Structures" and their sub categories, and the major crops grown in them. The following text will therefore focus on the acreage of four main crops / crop groups grown in "Closed Walk-In Structures":

Solanacea (e.g. tomatoes, peppers, aubergines), cucurbits with edible peel (e.g. cucumbers), lettuce, cut flowers and pot ornamentals

Regarding the selected four crop groups more than 78,000 ha of growing area are covered with closed walk-in structures in Europe. Most of these structures are located in the southern zone (66% = c. 51,500 ha), followed by the central zone (32% = c. 25,000 ha). Only 2% (c. 1,500 ha) can be found in the northern zone (Figure 2.1). The three countries with the largest areas closed walk-in structures are Spain, Italy and the Netherlands with acreages of 22,000, 20,000 and 8,500 ha respectively.

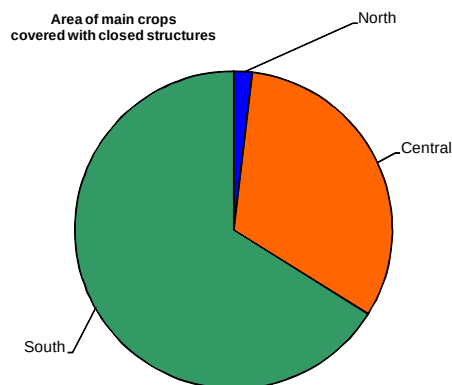


Figure 2.1: Distribution of areas of main crops grown in greenhouses in Europe. Total area 78,000 ha.

With regard to relative densities of closed structures in Europe, the ranking between the countries has changed. In the Netherlands the relative density (area closed walk-in structure divided by total land area) is highest (0.25%), followed by Belgium (0.1%), Italy (0.07%) and Spain (0.04%). The area relative to total arable area in the Netherlands is approximately 0.8%. See Appendix C for more statistics.

In view of scenario development for environmental risk assessment, the total area is important, but so is the location of the covered crop. The location determines, for example, the prevailing climatic conditions and the soil type (relevant for soil-bound cultivation). Therefore it is important to have an idea on the regional distribution as well. Closed walk-in structures are typically concentrated in specific areas; for example: near Ragusa in Sicily, near Almeria in Spain and in the Westland area in the Netherlands. In the Westland area 75% of the cultivated area is occupied by greenhouses (<http://www.cbs.nl/nl-NL/menu/themas/landbouw/publicaties/artikelen/archief/2009/2009-glasiuinbouw-2008-art.htm>). Available statistical information is not usually that detailed, but the differences in regional densities can be observed even if information is gathered at NUTS 2 level (Figure 2.2). In the Netherlands more than half of the acreage of greenhouses is located in the province of Zuid-Holland. The three major areas in Italy are Campania, Lazio and Sicily, while approximately 75% of the closed walk-in structures in Spain are located in Andalucia. In Figure 2.2 an extreme example of the so-called capital effect can be observed for Austria.

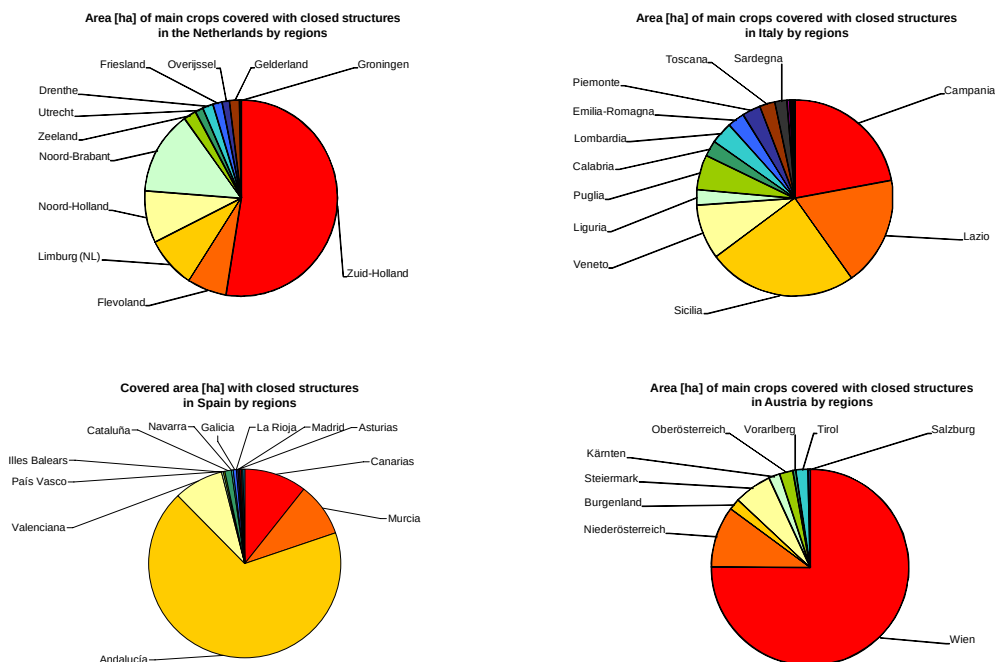


Figure 2.2: Regional distribution of closed walk-in structures in the Netherlands (upper left), Spain (lower left), Italy (upper right) and Austria (lower right).

Figure 2.3 gives examples of the distribution of the solanacea cultivation in different types of closed walk-in structures in Italy and the Netherlands (on a logarithmic scale). The Netherlands distinguishes between walk-in tunnels and greenhouses. Most greenhouses in the Netherlands are of the high-tech type. In Italy both low-tech and high-tech greenhouses occur frequently. In Italy the walk-in tunnel is the dominant type of structure while in the Netherlands this is the high-tech greenhouse.

2.3. Conclusion from the statistics

The preceding sections indicate that closed walk-in structures occur in approximately 78,000 ha in Europe. This seems to be only a fraction of the total area of crops under cover, but statistical information on smaller structures and more open structures is missing. Presumably this is because the circumstances in such systems resemble the open field more closely.

The closed walk-in structures are not distributed evenly over the area. First of all, the area in the southern zone is much larger than in the central and the northern zones. Secondly, the occurrence of these structures is concentrated in regions, sometimes in the neighbourhood of larger cities but often in areas where special conditions with respect to infrastructure or specific environmental conditions consist. This specific distribution over the area should be taken into account when deriving scenarios for risk assessment in covered crops.

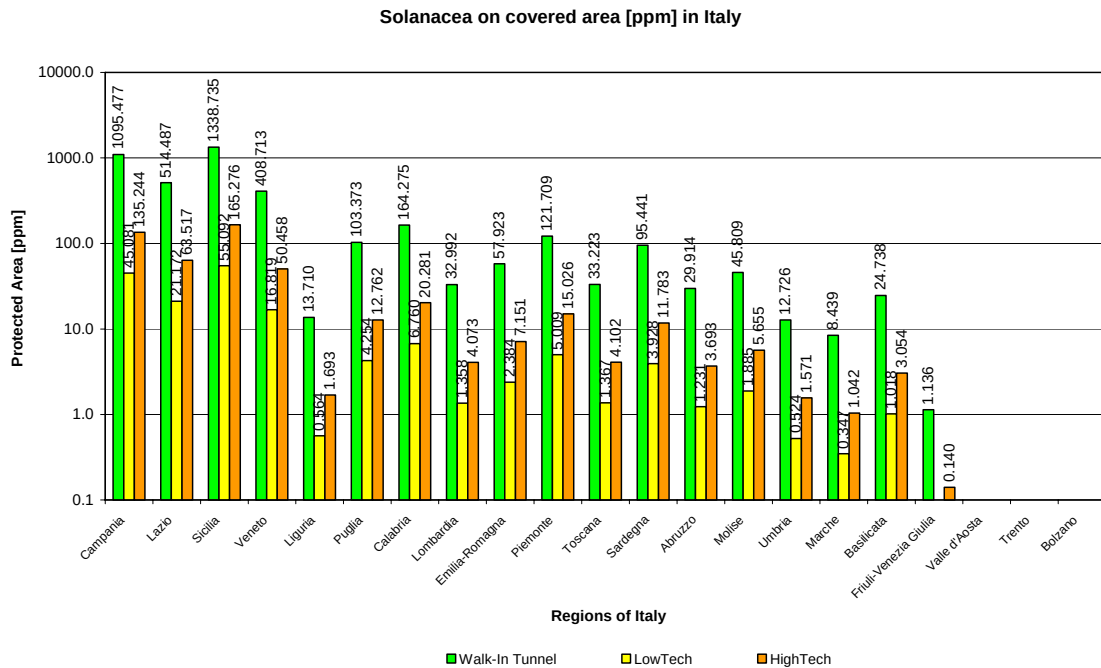
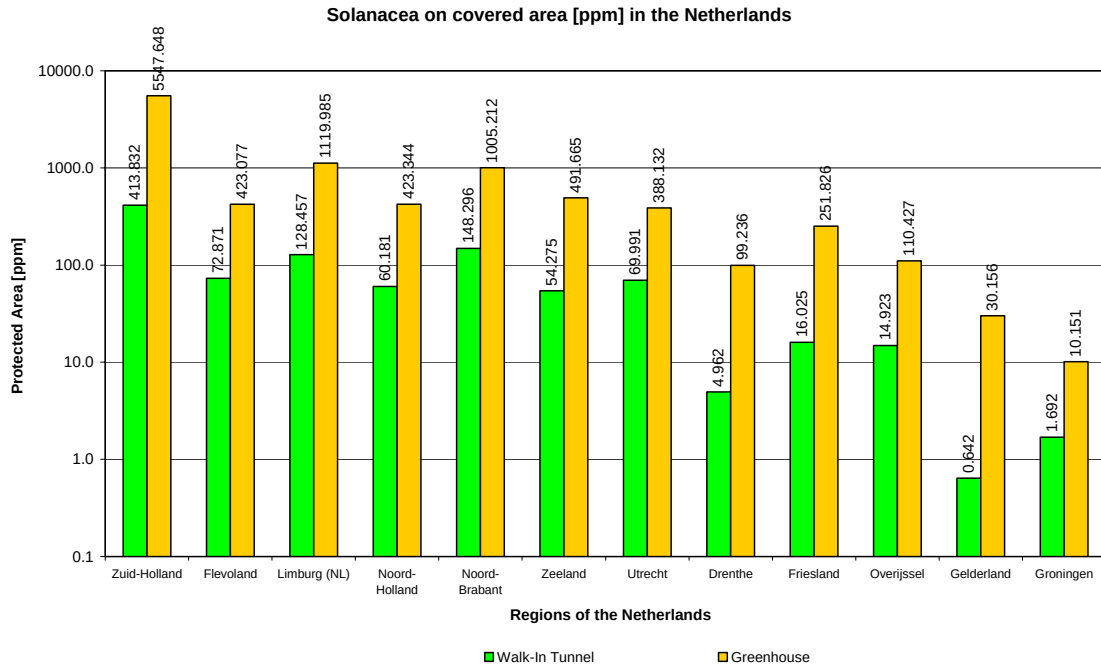


Figure 2.3: Density of solanacea in provinces in the Netherlands (top) and Italy (bottom). The density is given in m^2 per 100 ha (ppm) Note the logarithmic Y-axis.

3. Identification of potential emission routes

The EFSA working group on emissions from protected crops identified a number of categories which can be used to derive lists of potential emissions of PPPs from covered crops (EFSA, 2010; see also Appendix B):

- 1 receptor: air, groundwater, sewage treatment plant, soil, surface water;
- 2 construction type: low tunnel, high net shelter, high plastic shelter, shade house, walk-in tunnel; greenhouse;
- 3 application type: Spraying, fogging/fumigation, through irrigation system, soil injection, soil treatment;
- 4 cultivation system: soil with no recirculation, soil with recirculation, soilless with no recirculation, soilless with recirculation;
- 5 emission route: 14 potential routes, see appendix A.

The potential number of combinations is large, namely $5 * 6 * 5 * 4 * 14 = 8,400$. However, in practice not all combinations will occur (or occur rather seldom). Furthermore, a number of combinations are considered to be outside the remit of the workgroup. The following text describes the procedure used to derive lists of combinations that need further consideration with respect to emissions to environmental receptors.

Tables 2 – 8 provide 2-dimensional cross-sections of potential combinations. The colours in the tables indicate:

- green** the combination will regularly occur in practice and is used for further considerations on scenario selection;
- white** the combination will not or will only rarely occur in practice and is not used for further considerations on scenario selection;
- yellow** the combination will regularly occur in practice, but is not used for further considerations on scenario selection, because of reasons given in the text;
- red** the combination is considered to be outside the remit of the workgroup; it is not investigated whether the combination is possible.

The following describes the process of reducing the number of combinations which need to be considered further.

The construction types differ with respect to the materials of which they consist and the way in which they isolate the crop from the surroundings. At the one extreme, the net or plastic shelter and the shade house are quite open to the surroundings whereas at the other extreme a glasshouse is rather closed although never fully airtight (except in a few still experimental set-ups). The construction type determines to a large extent the possible existence of an emission route and its magnitude.

A soilless cultivation goes along with emission routes which are quite different from the emission routes that go along with soil-bound cultivation. Recycling will usually lead to lower emissions as it will give more time to plant uptake, dissipation and degradation processes.

Application techniques have been grouped into five categories. The techniques differ with respect to the primary target and as such may influence the possible emissions. The category DI (application along with (drip) irrigation or with the nutrient solution) includes all application techniques in which a PPP is applied along with the nutrient solution or water. The water / nutrient solution may be recycled.

The category FogFum (fogging or fumigation) includes all application techniques with which sometimes rather volatile PPPs are brought into the air space of the construction type (the space rather than the crop is treated) The category Spray includes all techniques with which a solution containing a PPP is sprayed onto the plant or onto the soil, i.e. the plant or the soil is the primary target. Soil applications are all applications, except injection, with which PPPs are brought into the soil, i.e. the PPP is applied in the soil or mixed through the soil immediately after application. Injection is an application of a volatile PPP at some depth in the soil, this is considered a separate application type because of the specific application technique and the rather high volatility of the substances applied with this technique.

Table 1 gives application types which are possible and occur regularly in the various construction types. The table indicates that FogFum application will usually not occur in rather open construction types. Injection may occur in low tunnels when the cover is absent or partly removed.

Table 1. Possible combinations of construction types and application types.

construction		application type				
		Drip irrigation	FogFum [#]	Injection	Spray	Soil Appl
LT	Low Tunnel					
WT	Walk-in Tunnel					
SH	Shade House					
PS	Plastic Shelter					
NS	Net Shelter					
GR	Greenhouse					

[#] Fogging or fumigation

Table 2 gives cultivation systems which occur regularly in the various constructions types. The table indicates that soilless cultivation mostly occurs in the more closed construction types, but may also be observed in WT and SH. It is recognised that recycling of water is rather expensive and therefore not likely to occur in combination with rather low cost construction types.

Table 2. Possible combinations of construction types and cultivation systems.

construction		cultivation system			
		Soil + Recirculation	Soilless + Recirculation	Soil no Recirculation	Soilless no Recirculation
LT	Low Tunnel				
WT	Walk-in Tunnel		*		
SH	Shade House		*		*
PS	Plastic Shelter				
NS	Net Shelter				
GR	Greenhouse				

Cultivation in pots or trays is considered to be a soilless cultivation. The pots / trays can be placed on a water-tight surface and then leaching / drainage routes may be small or negligible. If the surface is not water-tight, for example a woven net, a PPP may be transported through the surface and emission to

groundwater or surface water via drainage may occur. This is taken into account. Emission via aerial routes will probably not differ from equivalent other soilless cultivation systems.

Table 3 gives possible combinations of application type and cultivation system. The table indicates that injection and soil application do not occur in soilless cultivation systems.

Table 3. Possible links between applications and cultivation systems.

		cultivation system			
		Soil + Recirculation	Soilless + Recirculation	Soil no Recirculation	Soilless no Recirculation
DI	Drip irrigation				
FogFum	Fogging or Fumigation				
Inj	Injection				
Spray	Spray				
SoilAp	Soil Application				

A further possibility to reduce the number of potential emissions is to 'add' emission type to the analysis. Tables 4 – 6 give possible combinations of emission routes and construction types, application types and cultivation systems respectively.

Table 4 gives possible combinations of emission types and construction types. Appendix B (Table B2) gives definitions and further explanation of the different emission types. Table 4 indicates that spray drift emission may occur in all construction types. The amounts lost by spray drift however may be quite different, where losses due to spray drift will be higher in more open systems and lower in more closed systems. The same holds for gas phase emission at the moment of application. Uncontrolled gas phase emission after application may occur in all construction types and the amounts will depend on the air tightness of the system. Controlled gas phase emissions will occur only in those construction types where openings can be regulated or where ventilators are installed.

Discharge of nutrient solution may only occur in those construction types in which waste water tanks are installed or used water is directly transferred to a receptor. In this route (E7) discharge of solution to flush back / clean filter installations is included. Emissions may also occur when rinsing water used for cleaning the system is discharged (E8). This latter emission is however considered to be outside the remit of the working group. Emission E8 can often not be attributed to a specific crop as it may result from cleansing of a protection structure after several crop cycles. In case biocides are used when cleaning the system, specific scenarios are probably necessary to quantify emissions from such applications. Controlled discharge of condensation is only possible when condensation is collected. Usually this is restricted to glasshouses and greenhouses. Leaching will only occur if the PPP reaches the soil.

Run-off can only occur in construction types without side walls or in construction types in which side walls are temporarily installed, or after a certain growth stage, removed. Furthermore, run-off will only occur when an amount of water in excess of the infiltration capacity of the soil reaches the soil. Such situations may, under normal conditions, only occur when the cover is rather open to penetration of water. Run-off may occur irrespective of the application type although the amounts emitted will

depend highly on the application type. For example, run-off may be limited when the PPP is injected into the soil.

Table 4. Possible combinations of emission types and construction types.

emission type	Construction					
	Greenhouse	Net Shelter	Low Tunnel	Plastic Shelter	Shade House	Walk-in Tunnel
E1 spray drift emission at moment of application						
E2 gas phase emission at moment of application						
E3 gas phase emission during compulsory ventilation						
E4 long-term gas phase emission, uncontrolled						
E5 long-term gas phase emission, regulated						
E6 Leaching						
E7 discharge from tank						
E8 discharge of rinse water						
E9 discharge of condensation, controlled						
E10 discharge of condensation, uncontrolled						
E11 run-off						
E12 removal of yield and non-yield biomass						
E13 removal of substrate / solid growing media						
E14 removal of plastic						

Emissions of PPPs may also occur when harvested products, plant remnants, used substrates and / or plastic covers are removed from the construction. As these emission routes, (E12 - E14), are either not different from equivalent routes in open field (E12) or regulated by law (E13-E14), these routes are considered to be outside the remit of the working group.

The cultivation system in which plants, for example ornamentals, rooted cuttings or seedlings, are grown in pots or trays is considered a soilless cultivation system. Both recycling and non-recycling of the nutrient solution may occur. At 'harvest', plants, often with the growing medium, are removed from the covered crop system. Plants and / or the growing medium may contain residues of PPPs. If these residues of PPPs are brought outside the covered crop system, this is considered an emission from the covered crop system, but it is considered outside the remit of the workgroup.

Table 5 gives possible combinations of emission types and application types. Spray drift emission may occur only if the PPP is sprayed. After spraying or fogging/fumigating, a part of the application amount may be in the gaseous phase or in very fine droplets that do not settle. This part may be

emitted to the outside in a very short period after application and is considered to be gas phase emission at the moment of application. The amount is dependent on the fraction of very fine droplets (< 100 micrometer diameter) and is influenced by a.o. nozzle type and tank pressure. Controlled and uncontrolled gas phase emissions after application may occur irrespective of the application type. Uncontrolled or controlled gas phase emission may be negligible if the PPP is applied to the nutrient solution in a soilless cultivation system.

Emissions with the discharge of condensation may occur along with all application types. It is however assumed that substances applied to the nutrient solution or with the water have such a high solubility and low vapour pressure that volatilisation of the substance can be considered negligible and consequently emission with the condensation water will not occur.

Table 5. Possible links emission types to application types

Emission type	Application type				
	Drip irrigation	FogFum [#]	Injection	Spray	Soil Appl
E1 spray drift emission at moment of application					
E2 gas phase emission at moment of application					
E3 gas phase emission during compulsory ventilation					
E4 long-term gas phase emission, uncontrolled					
E5 long-term gas phase emission, regulated					
E6 Leaching					
E7 discharge from tank					
E8 discharge of rinse water					
E9 discharge of condensation, controlled					
E10 discharge of condensation, uncontrolled					
E11 run-off					
E12 removal of yield and non-yield biomass					
E13 removal of substrate / solid growing media					
E14 removal of plastic					

[#] Fogging or fumigation

Table 6 gives possible combinations of emission types and cultivation systems. Spray drift emissions and gas phase emissions may occur irrespective of the cultivation system. Run-off may occur only from soil-bound cultivations. Discharge of nutrient solution and / or rinse water will not occur from soil bound cultivations. It is assumed that cultivation systems with recirculation all have a facility to capture condensation and that this water is discharged in a controlled manner. Removal of substrate and plastic will not occur in soil-bound cultivations.

Table 6. Possible combinations of emission types and cultivation systems

Emission type	Cultivation system			
	Soil + Recirculation	Soilless + Recirculation	Soil no Recirculation	Soilless no Recirculation
E1 spray drift emission at moment of application				
E2 gas phase emission at moment of application				
E3 gas phase emission during compulsory ventilation				
E4 long-term gas phase emission, uncontrolled				
E5 long-term gas phase emission, regulated				
E6 Leaching				
E7 discharge from tank				
E8 discharge of rinse water				
E9 discharge of condensation, controlled				
E10 discharge of condensation, uncontrolled				
E11 run-off				
E12 removal of yield and non-yield biomass				
E13 removal of substrate / solid growing media				
E14 removal of plastic				

Finally possible links between emission types and receptors may be useful (see Table 7). Spray drift emissions will be relevant for the receptors soil and surface water. Generally spray drift is not considered to be an emission to air; air is only a transport medium for a short time. So spray drift is not considered an emission route to air. Groundwater and a sewage treatment plant will not be directly exposed by spray drift. The sewage treatment plant will be too distant to be influenced by spray drift. Gas phase emissions will be relevant for the air compartment. Atmospheric deposition may also be relevant for soil and surface water. Gaseous emissions may eventually reach soil or surface water. Here, emissions into soil or surface water are considered indirect routes.

Run-off is only considered relevant for the receptors soil and surface water. Discharge of water is considered relevant for surface water and sewage treatment plant. Uncontrolled emission of condensation may also end up in soil as a small strip of soil along the walls of the construction types may be exposed. Leaching is only relevant for the groundwater compartment.

The working group did not consider it appropriate to link emission types E12 – E14 to receptors. Emissions of these types are not restricted to covered crops. It does not seem necessary to develop emission scenarios for these emission routes separate from cultivations in the open field.

Table 7. Possible links of emissions to receptors

Emission type	Receptor				
	Air	GroundWater	Soil	STP [#]	Surface Water
E1 spray drift emission at moment of application					
E2 gas phase emission at moment of application					
E3 gas phase emission during compulsory ventilation					
E4 long-term gas phase emission, uncontrolled					
E5 long-term gas phase emission, regulated					
E6 Leaching					
E7 discharge from tank					
E8 discharge of rinse water					
E9 discharge of condensation, controlled					
E10 discharge of condensation, uncontrolled					
E11 run-off					
E12 removal of yield and non-yield biomass					
E13 removal of substrate / solid growing media					
E14 removal of plastic					

[#] Sewage Treatment Plant

4. Potential emission routes for air, groundwater and surface water

Application of the 'rules' as described in chapter 3, Tables 1 – 7, leads to tables indicating potential emissions from covered crop systems. The resulting tables are listed in this chapter. The combinations with potential emissions to air are listed in Table 8 (section 4.1), to groundwater in Table 9 (section 4.2) and to surface water in Table 10 (section 4.3). Listing of a combination in one or more of Tables 8 – 10 only indicates that there is potentially an emission, and **not** that the emission is relevant in terms of having an impact on the respective environmental receptors. Also, the lists are not ranked with respect to the amount of emission that may occur.

EFSA (2010) considered that risk assessment for soil in a covered crop system (when applicable) is likely to be covered by assessment methods for the open field. The soil compartment is therefore not included in this chapter. Also emission to sewage treatment plants is not included in this chapter. Emissions to a sewage treatment plant will either be covered by scenarios for surface water or do not exist at all. Concentrations in surface water after STP passage may differ; in general they are expected to be lower as a STP usually discharges its water in larger water bodies.

4.1. Emission routes to air

Table 8 lists combinations of construction, system, applications type and emission type which remain for the receptor air after application of the 'rules' described in chapter 3. Although the number of potential combinations has been reduced considerably, the number of remaining combinations is large (93 possible combinations) and needs to be reduced.

The following considerations were applied in order to reduce the number of combinations to be considered for scenario development. The considerations do **not** indicate that the emissions are negligible, but solely that they can be neglected when selecting / developing scenarios. The consequence is that the scenarios are used for the assessment of situations that have been excluded here as well. When deriving (representative) scenarios, the acreage involved in the techniques should be included in the considerations.

- 1336 1. Soil injection is applicable only for a few substances. It does not seem to be justifiable to base
1337 scenario selection on that.
- 1338 2. Soil and DI applications will have lower emissions to air, because interaction with soil and
1339 passage through soil is necessary before emission can occur.
- 1340 3. Spray application and fogging / fumigation may differ somewhat with respect to emission to
1341 air because droplets size spectra differ. As a result, emissions to air may be somewhat larger
1342 for FogFum applications.
- 1343 4. Emissions to air from soilless systems after spraying or fogging do probably not differ much
1344 from emissions to air from soil-bound systems. Also, water management in these systems
1345 probably does not influence emissions significantly. For example, spray drift emissions from a
1346 spray application of a crop grown soilless with recirculation will be the same as the spray drift
1347 emission of the same crop grown soilless without recirculation. So such combinations are not
1348 considered different regarding emissions to air.
- 1349 The further selection / clustering leads to selecting Spray application or FogFum application as the
1350 basis for further scenario development. Additional information on emissions and comparisons with the
1351 open field is necessary to further reduce the number of potential scenarios. Montanari *et al.* (2011)
1352 report that spraying is by far the most used application technique, so it is recommended here that this
1353 technique is chosen for scenario selection and development.
- 1354 Possibly further reduction of the number can take place when the most important emission route is
1355 taken into account or when emission routes are combined. For example, contributions of different
1356 emission routes may vary across combinations, but the total of these emissions might almost be the
1357 same for substances with longer half-lives. This needs to be examined further.
- 1358 Whether or not scenarios need to be developed also depends on considerations regarding whether the
1359 situation must be considered different from the open field. This will be addressed later by the working
1360 group.
- 1361

Table 8. Potential emission routes to the receptor air. In red, combinations that will not be considered for further selection.

construction	system	application	emission	construction	system	application	emission
GR	SnoR	Spray	E2	GR	SL+R	FogFum	E5
LT	SnoR	Spray	E2	GR	SLnoR	FogFum	E5
NS	SnoR	Spray	E2	GR	SnoR	FogFum	E5
PS	SnoR	Spray	E2	GR	S+R	DI	E3
SH	SnoR	Spray	E2	GR	SL+R	DI	E3
WT	SnoR	Spray	E2	GR	SLnoR	DI	E3
GR	SnoR	Spray	E3	GR	SnoR	DI	E3
GR	SnoR	Spray	E4	GR	S+R	DI	E4
LT	SnoR	Spray	E4	GR	SL+R	DI	E4
NS	SnoR	Spray	E4	SH	SL+R	DI	E4
PS	SnoR	Spray	E4	WT	SL+R	DI	E4
SH	SnoR	Spray	E4	GR	SLnoR	DI	E4
WT	SnoR	Spray	E4	SH	SLnoR	DI	E4
GR	SnoR	Spray	E5	WT	SLnoR	DI	E4
GR	S+R	Spray	E2	GR	SnoR	DI	E4
GR	SL+R	Spray	E2	LT	SnoR	DI	E4
SH	SL+R	Spray	E2	NS	SnoR	DI	E4
WT	SL+R	Spray	E2	PS	SnoR	DI	E4
GR	SLnoR	Spray	E2	SH	SnoR	DI	E4
SH	SLnoR	Spray	E2	WT	SnoR	DI	E4
WT	SLnoR	Spray	E2	GR	S+R	DI	E5
GR	S+R	Spray	E3	GR	SL+R	DI	E5
GR	SL+R	Spray	E3	GR	SLnoR	DI	E5
GR	SLnoR	Spray	E3	GR	SnoR	DI	E5
GR	S+R	Spray	E4	GR	S+R	SoilAp	E3
GR	SL+R	Spray	E4	GR	SnoR	SoilAp	E3
SH	SL+R	Spray	E4	GR	S+R	SoilAp	E4
WT	SL+R	Spray	E4	GR	SnoR	SoilAp	E4
GR	SLnoR	Spray	E4	LT	SnoR	SoilAp	E4
SH	SLnoR	Spray	E4	NS	SnoR	SoilAp	E4
WT	SLnoR	Spray	E4	PS	SnoR	SoilAp	E4
GR	S+R	Spray	E5	SH	SnoR	SoilAp	E4
GR	SL+R	Spray	E5	WT	SnoR	SoilAp	E4
GR	SLnoR	Spray	E5	GR	S+R	SoilAp	E5
GR	S+R	FogFum	E2	GR	SnoR	SoilAp	E5
GR	SL+R	FogFum	E2	GR	S+R	Inj	E3
GR	SLnoR	FogFum	E2	GR	SnoR	Inj	E3
GR	SnoR	FogFum	E2	GR	S+R	Inj	E4
GR	S+R	FogFum	E3	GR	SnoR	Inj	E4
GR	SL+R	FogFum	E3	LT	SnoR	Inj	E4
GR	SLnoR	FogFum	E3	NS	SnoR	Inj	E4
GR	SnoR	FogFum	E3	PS	SnoR	Inj	E4
GR	S+R	FogFum	E4	SH	SnoR	Inj	E4
GR	SL+R	FogFum	E4	WT	SnoR	Inj	E4
GR	SLnoR	FogFum	E4	GR	S+R	Inj	E5
GR	SnoR	FogFum	E4	GR	SnoR	Inj	E5
GR	S+R	FogFum	E5				

4.2. Emission routes to groundwater

Table 9 lists combinations of construction, system, application type and emission type which remain for the receptor groundwater after application of the ‘rules’ described in chapter 3. Although the number of potential combinations has been considerably reduced, the number of remaining combinations is still too large (30 possible combinations) and needs to be reduced.

The following considerations were applied to reduce the number of combinations to be considered for scenario development. The considerations do **not** indicate that the emissions are negligible, but solely that they can be neglected when selecting / developing scenarios. The consequence is that the scenarios are used for the assessment of the here excluded situations as well. When deriving (representative) scenarios, the acreage involved in the techniques should be included in the considerations.

1. Soil injection is applicable only for a few substances. It does not seem justifiable to base scenario selection on that.
2. For soil-bound cultivations, drip irrigation cannot be simulated with models currently used in evaluation. Therefore, at the moment it is impossible to include this application type in the procedure for deriving appropriate scenarios. At the moment, the most appropriate approach seems to be deriving scenarios using one or more other application types. It may then be necessary to correct for potentially different emissions, based on considerations as provided by Leistra *et al.* (1984).
3. Recirculation is seldom done in soil-bound cultivation. As it is anticipated that leaching to groundwater will be less than leaching in a situation without recirculation, it is considered not necessary to include this in the scenario selection.
4. If deposition on the soil surface is the same, there will be no difference in emissions between the application types FogFum and Spray. Presumably, deposition is somewhat lower for FogFum and therefore Spray is recommended for scenario development.

The further selection / clustering leads to selecting Spray application or FogFum application as the basis for further scenario development. Additional information on emissions and comparisons with the open field is necessary to further reduce the number of potential scenarios.

1394 Table 9. Potential emission routes to the receptor groundwater. In red, combinations that will not be
1395 considered for further selection.

construction	system	application	emission
GR	SnoR	Spray	E6
LT	SnoR	Spray	E6
NS	SnoR	Spray	E6
PS	SnoR	Spray	E6
SH	SnoR	Spray	E6
WT	SnoR	Spray	E6
GR	SnoR	SoilAp	E6
LT	SnoR	SoilAp	E6
NS	SnoR	SoilAp	E6
PS	SnoR	SoilAp	E6
SH	SnoR	SoilAp	E6
WT	SnoR	SoilAp	E6
GR	SnoR	FogFum	E6
GR	S+R	FogFum	E6
GR	S+R	SoilAp	E6
GR	S+R	Spray	E6
GR	S+R	DI	E6
GR	SnoR	DI	E6
LT	SnoR	DI	E6
NS	SnoR	DI	E6
PS	SnoR	DI	E6
SH	SnoR	DI	E6
WT	SnoR	DI	E6
GR	S+R	Inj	E6
GR	SnoR	Inj	E6
LT	SnoR	Inj	E6
NS	SnoR	Inj	E6
PS	SnoR	Inj	E6
SH	SnoR	Inj	E6
WT	SnoR	Inj	E6

1396

1397

1398 4.3 Emission routes to surface water

1399 Table 10 lists combinations of constructions, systems, application types and emission types which
1400 remain for the receptor surface water after application of the ‘rules’ described in chapter 3. Although
1401 the number of potential combinations has been considerably reduced, the number of remaining
1402 combinations is still too large (93 possible combinations) and needs to be reduced.

1403 The following considerations were applied to reduce the number of combinations to be considered for
1404 scenario development. The considerations do **not** indicate that the emissions are negligible, but solely
1405 that they can be neglected when selecting / developing scenarios. The consequence is that the
1406 scenarios are used for the assessment of the situations excluded here as well. When deriving
1407 (representative) scenarios, the acreage involved in the techniques should be included in the
1408 considerations.

- 1409 1. Soil injection is only applicable for a few substances. It does not seem justifiable to base
1410 scenario selection on that.
- 1411 2. For soil-bound cultivations, drip irrigation cannot be simulated with models currently used in
1412 evaluation. Therefore, at the moment it is impossible to include this application type in the
1413 procedure for deriving appropriate scenarios. At the moment, the most appropriate approach
1414 seems to be deriving scenarios using one or more other application types. It may then be
1415 necessary to correct for potentially different emissions to surface water, based on
1416 considerations similar to those provided by Leistra *et al.* (1984) for leaching to groundwater.
- 1417 3. Soil application with mixing of the substance through the soil will be the application type for a
1418 minority of substances. For most of these substances, this application type is chosen in order
1419 to diminish losses by volatilisation. Drainage is expected to be equal or lower compared to
1420 spray or FogFum applications. The emission is expected to be lower when, as a result of
1421 preferential flow, water is bypassing the areas where most of the substance resides.
- 1422 4. Montanari *et al* (2011) report that spraying is by far the most used application technique, so it
1423 is recommended here that this technique is chosen for scenario selection and development.
- 1424 5. Recirculation is seldom done in soil-bound cultivation. As it is anticipated that drainage to
1425 surface water will be less than drainage in a situation without recirculation, it is considered not
1426 necessary to include this in the scenario selection.
- 1427 6. Spray drift emissions will not be influenced by the growing system.
- 1428 7. Soilless growing systems occur much more frequently in greenhouses than in other
1429 construction types. It seems to be justified to base scenarios only for greenhouses for this
1430 situation.
- 1431 Soilless cultivations are quite different from soil cultivations regarding the emission route ‘discharge
1432 to surface water’. Such systems cannot be combined with other systems.
1433

1434 Table 10. Potential emission routes to the receptor surface water. In red, combinations that will not be
1435 considered for further selection.

construction	system	application	emission	construction	system	application	emission
GR	SnoR	Spray	E1	GR	SL+R	FogFum	E10
LT	SnoR	Spray	E1	GR	SLnoR	FogFum	E10
NS	SnoR	Spray	E1	GR	SnoR	FogFum	E10
PS	SnoR	Spray	E1	GR	S+R	FogFum	E6
SH	SnoR	Spray	E1	GR	SnoR	FogFum	E6
WT	SnoR	Spray	E1	GR	S+R	FogFum	E9
GR	SnoR	Spray	E10	GR	SL+R	FogFum	E9
LT	SnoR	Spray	E10	GR	SLnoR	FogFum	E9
NS	SnoR	Spray	E10	GR	S+R	SoilAp	E10
PS	SnoR	Spray	E10	GR	SnoR	SoilAp	E10
SH	SnoR	Spray	E10	GR	S+R	SoilAp	E6
WT	SnoR	Spray	E10	GR	SnoR	SoilAp	E6
GR	SnoR	Spray	E6	GR	S+R	SoilAp	E9
LT	SnoR	Spray	E6	LT	SnoR	SoilAp	E10
NS	SnoR	Spray	E6	LT	SnoR	SoilAp	E6
PS	SnoR	Spray	E6	NS	SnoR	SoilAp	E10
SH	SnoR	Spray	E6	NS	SnoR	SoilAp	E6
WT	SnoR	Spray	E6	PS	SnoR	SoilAp	E10
GR	SL+R	DI	E7	PS	SnoR	SoilAp	E6
GR	SLnoR	DI	E7	SH	SnoR	SoilAp	E10
GR	SL+R	Spray	E9	SH	SnoR	SoilAp	E6
SH	SL+R	DI	E7	WT	SnoR	SoilAp	E10
SH	SLnoR	DI	E7	WT	SnoR	SoilAp	E6
WT	SL+R	DI	E7	GR	S+R	DI	E6
WT	SLnoR	DI	E7	GR	SnoR	DI	E6
GR	SL+R	Spray	E10	GR	S+R	DI	E7
GR	SLnoR	Spray	E10	LT	SnoR	DI	E6
SH	SL+R	Spray	E10	NS	SnoR	DI	E6
SH	SLnoR	Spray	E10	PS	SnoR	DI	E6
WT	SL+R	Spray	E10	SH	SnoR	DI	E6
WT	SLnoR	Spray	E10	WT	SnoR	DI	E6
GR	SLnoR	Spray	E9	GR	S+R	Inj	E10
GR	SL+R	Spray	E1	GR	SnoR	Inj	E10
GR	SLnoR	Spray	E1	GR	S+R	Inj	E6
SH	SL+R	Spray	E1	GR	SnoR	Inj	E6
SH	SLnoR	Spray	E1	GR	S+R	Inj	E9
WT	SL+R	Spray	E1	LT	SnoR	Inj	E10
WT	SLnoR	Spray	E1	LT	SnoR	Inj	E6
GR	S+R	Spray	E1	NS	SnoR	Inj	E10
GR	S+R	Spray	E10	NS	SnoR	Inj	E6
GR	S+R	Spray	E6	PS	SnoR	Inj	E10
GR	S+R	Spray	E9	PS	SnoR	Inj	E6
GR	S+R	FogFum	E1	SH	SnoR	Inj	E10
GR	SL+R	FogFum	E1	SH	SnoR	Inj	E6
GR	SLnoR	FogFum	E1	WT	SnoR	Inj	E10
GR	SnoR	FogFum	E1	WT	SnoR	Inj	E6
GR	S+R	FogFum	E10				

1436

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Covered crop cultivation constitutes a significant part of crop cultivation in Europe. Statistical information however does not cover the small and more open structures. Only closed walk-in structures, i.e. walk-in tunnels, low-tech and high-tech greenhouses, are included to some extent in the statistics. Four major crops grown in walk-in structures are solanacea, cucurbits, lettuce and ornamentals/pot plants. These crops cover in total around 78,000 ha in Europe. The total area is significant with regard to risk assessment of plant protection products.

Potential emission routes to receptors air, groundwater and surface water were investigated. The following routes need to be investigated further:

Air

The number of potential combinations remaining for further selection for the receptor air could be reduced from 93 to 14 by considering that emissions after applications which bring PPP into the soil (DI, Inj, SoilApp) will be lower than emissions after spray or fogging/fumigation application. Of the latter two, spraying is the most frequently used technique and this was used as a selection criterion. Soil bound and soilless cultivation are not expected to differ much from each other. Results from emission-to-air calculations for different construction types and comparison with open field may reduce the number of construction types that need to be included in further considerations for scenario development.

Table 11. Combinations remaining for further consideration for the receptor air

construction	system	application	emission
GR	SnoR	Spray	E2
GR	SnoR	Spray	E3
GR	SnoR	Spray	E4
GR	SnoR	Spray	E5
LT	SnoR	Spray	E2
LT	SnoR	Spray	E4
NS	SnoR	Spray	E2
NS	SnoR	Spray	E4
PS	SnoR	Spray	E2
PS	SnoR	Spray	E4
SH	SnoR	Spray	E2
SH	SnoR	Spray	E4
WT	SnoR	Spray	E2
WT	SnoR	Spray	E4

Groundwater

The number of combinations to be taken into account for leaching assessment could be drastically reduced. Only soil-bound cultivation and soilless without recirculation are relevant for leaching assessment. The application type drip irrigation cannot be handled properly by current leaching models. Soilless cultivation without recirculation, like drip irrigation, cannot be handled properly by current leaching models. Soil injection and soil application are relevant for a minority of substances. Based on expert judgement, a choice between spray applications or a fogging or fumigation application can be made. Results from leaching calculations for different construction types and comparison with the open field may reduce the number of construction types that need to be included in further considerations for scenario development.

Table 12. Combinations remaining for further consideration for the receptor groundwater

construction	system	application	emission
GR	SnoR	Spray	E6
LT	SnoR	Spray	E6
NS	SnoR	Spray	E6
PS	SnoR	Spray	E6
SH	SnoR	Spray	E6
WT	SnoR	Spray	E6

Surface water

The number of combinations to be taken into account for assessment of emissions to surface water could also be drastically reduced. Spray application is by far the most important application technique for soil-bound cultivation. Drift, drainage and condensation are the most important direct emission routes to surface water that should be taken into account. As for the receptor groundwater, emissions following drip irrigation cannot be handled by current models. Also here, further comparison with open field cultivations may reduce the number of combinations to consider further.

Soilless cultivations have no equivalents in open fields when considering emissions to surface water.

Table 13 Combinations remaining for further consideration for the receptor surface water.

construction	system	application	emission
GR	SnoR	Spray	E1
LT	SnoR	Spray	E1
NS	SnoR	Spray	E1
PS	SnoR	Spray	E1
SH	SnoR	Spray	E1
WT	SnoR	Spray	E1
GR	SnoR	Spray	E10
LT	SnoR	Spray	E10
NS	SnoR	Spray	E10
PS	SnoR	Spray	E10
SH	SnoR	Spray	E10
WT	SnoR	Spray	E10
GR	SnoR	Spray	E2
LT	SnoR	Spray	E2
NS	SnoR	Spray	E2
PS	SnoR	Spray	E2
SH	SnoR	Spray	E2
WT	SnoR	Spray	E2
GR	SnoR	Spray	E6
LT	SnoR	Spray	E6
NS	SnoR	Spray	E6
PS	SnoR	Spray	E6
SH	SnoR	Spray	E6
WT	SnoR	Spray	E6
GR	SL+R	DI	E7
GR	SLnoR	DI	E7
GR	SLnoR	Spray	E9

5.2. Recommendations

Statistical information on covered crops up till now suffers from different definitions at national level and therefore is not easily combined at the EU level. Furthermore, the information is only gathered for the more permanent structures and information on smaller and more open structures is missing. It is recommended that the information is gathered for a longer period of time, according to the definitions established by EFSA. Application via drip irrigation cannot be handled by models used in current risk assessment, as is the case for the open field. As drip irrigation is becoming more important, it is recommended to develop or adapt models so that this application type can be taken into account.

FOCUS (2008) recommends including atmospheric deposition on surface water in risk assessment as this may contribute significantly to exposure to PPPs when drift reducing measures are taken. It is recommended to follow this recommendation in case of emissions of PPPs from covered crops to air. It seems necessary to develop or adapt methodology to calculate the occurring deposition.

DOCUMENTATION PROVIDED TO EFSA

No information was submitted.

REFERENCES

Sas Paszt L, 2010. Data-collection of existing data on protected crop systems (greenhouses and crops grown under cover) in Eastern European Member States in EU. The Research Institute of Pomology and Floriculture, Poland, 47 pp. Question number: EFSA-Q-2008-05004 <http://www.efsa.europa.eu/en/supporting/doc/32e.pdf>

Sigrimis N, Cavallini A, Incrocci I, Montero J I, Parra J P and Kafka A, 2010. Data-collection of existing data on protected crop systems (greenhouses and crops grown under cover) in southern European Member States in EU. University of Athens, Greece, 192 pp. Question number: EFSA-Q-2008-05003. <http://www.efsa.europa.eu/en/supporting/doc/31e.pdf>

EFSA Panel on Plant Protection Products and their Residues (PPR), 2010. Scientific Opinion on emissions of plant protection products from greenhouses and crops grown under cover: outline for a new guidance. EFSA Journal 2010; 8(4):1567. (44 pp). Doi:10.2903/j.efsa.2010.1567. Available online: www.efsa.europa.eu.

Saunders N, 2010. Collection and Evaluation of relevant information for the development of a new Guidance document on Emissions of Plant Protection Product from Protected Crops (e.g. greenhouses and crops grown under cover) – data collection for four study regions in the central zone as defined in the draft regulation on “Placing Protection Products on the Market”. Campden BRI, UK, 167 pp. Question number: EFSA-Q-2009-01086. <http://www.efsa.europa.eu/en/supporting/doc/76e.pdf>

EFSA, 2011. Data-collection of existing data on protected crop systems (greenhouses and crops grown under cover) in central and northern European Member States in EU. In prep.

Montanari S, Minuto A, Tinivella F, Minuto G and Delfino G, 2011. Collection and Evaluation of relevant information for the development of a new Guidance document on Emissions of Plant Protection Product from Protected Crops (e.g. greenhouses and crops grown under cover) – data collection for four study regions in the southern zone as defined in the draft regulation on “Placing Protection Products on the Market”. Centro di Sperimentazione ed Assistenza Agricola, Savona, Italy. 147 pp. EFSA-Q-2010-01467. <http://www.efsa.europa.eu/en/supporting/doc/106e.pdf>

Beulke S, van Beinum W, Glass R, van Os E, Hoterman H J, Sapounas A, Voogt W, van de Zande J, de Zwart F and Garratt J, 2011. Estimation/calculation of emissions of Plant Protection Products from protected crops greenhouses and cultivations grown under cover) to support the Development of risk assessment methodology under Council Directive 91/414/EEC and EU regulation

- 1527 1107/2009 (EC). Consortium. 126 pp, EFSA-Q-2010-00830.
 1528 <http://www.efsa.europa.eu/en/supporting/pub/151e.htm>
 1529
 1530 FOCUS, 2008. Pesticides in Air: Considerations for Exposure Assessment. Report of the FOCUS
 1531 Working Group on Pesticides in Air, EC Document Reference SANCO/10553/2006 Rev 2 June
 1532 2008. 327 pp.
 1533
 1534 Gonzalez-Pradas E, Urena-Amate E M D, Flores-Cespedes F, Fernandez-Perez M, Garratt J and
 1535 Wilkins R, 2002 Leaching of imidacloprid and procymidone in a greenhouse of southeast of Spain.
 1536 Soil Sci. Soc. Am. J. 66 (6): 1821-1828 pp
 1537 Leistra M, A Dekker, AMM Vanderburg. 1984. Computed and measured leaching of the insecticide
 1538 methomyl from greenhouse soils into water courses. Water Air and Soil Pollution 23:155-167 pp.
 1539 Stanghellini C, 2009. Emissions by aerial routes from protected crop systems (greenhouses and crops
 1540 grown under cover): a position paper. Wageningen UR Greenhouse Horticulture, The Netherlands.
 1541 Report 224: 21 pp. Technical report to EFSA under procurement NP/EFSA/PPR/2008/03.
 1542 <http://www.efsa.europa.eu/en/supporting/doc/10e2.pdf>
 1543 Van der Linden AMA, 2009. Emissions by “other routes than air” from protected crop systems:
 1544 Position paper RIVM report 607050004. The Netherlands. Technical report to EFSA under
 1545 procurement NP/EFSA/PPR/2008/04. <http://www.efsa.europa.eu/en/scdocs/scdoc/10e.htm>

1546 GLOSSARY/ABBREVIATIONS

a.s.	active substance
closed-loop	irrigation system in which the water is, partly, recirculated
EC	European Community
EEC	European Economic Community
EFSA	European Food Safety Authority
Enarenado	Cultivation practice in arid areas of Spain and the Canary Islands. The practice entails placing a layer of sandy soil (10 – 30 cm) over a very clay-rich soil.
emission	technical term signifying the transfer of a substance over a boundary usually presented as a percentage of the applied dose
ERA	Environmental Risk Assessment
EU	European Union
FOCUS	FORum for the Co-ordination of pesticide fate models and their USE
GPFM	Greenhouse Pesticide Fate Model
GW	groundwater
NFT	nutrient film technique
NUTS	Nomenclature of Territorial Units for Statistics
PEC	Predicted Environmental Concentration
PECair	PEC in air
PECsoil	PEC in soil
PECsw	PEC in surface water
PPP	plant protection product
PPR	Panel on Plant Protection Products and their Residues
PRAPeR	(former) Pesticide Risk Assessment Peer Review
protection	The word “protection” is often used to refer to physical barriers (i.e. plastic, glass or netting) or to refer to chemical / biological products that are applied to the crop (e.g. pesticides or plant growth regulators). Since this term could be ambiguous, we have chosen to use the term “PPP” to refer to products (Plant Protection Products). When the word ”protection” or “protected” appears, it refers to the physical barriers.

receptor	For the purpose of this opinion, a receptor is an environmental compartment receiving emissions, such as surface water, air, soil and groundwater.
RIPF	Research Institute of Pomology and Floriculture (Poland)
RIVM	National Institute for Public Health and the Environment in the Netherlands
SE	South East
solids	For the purpose of this opinion, solids are defined as solid materials such as plastic covers, plant residues, soil and substrate that can be removed from the protected structure.
substrate	any material, not in connection with subsoil, used for growing plants on
UV	Ultra Violet light
WATERSTRO	model for calculating distribution of water to plants in greenhouses
MEN	
WG	Working Group

1547

1548 **APPENDICES**

1549 **CODES AND ACRONYMS FOR THE TECHNICAL TERMS FOR THE GREENHOUSES GROUP**

1550 Codes for receptors:

1	Receptor	2	Code
3	Air	4	Air
5	Ground water	6	GW
7	Soil	8	Soil
9	Sewerage Treatment Plant	10	STP
11	Surface Water	12	SW

1551

1552 Codes for constructions:

13	Construction	14	code
15	Greenhouse	16	GR (GH)
17	High Net Shelter	18	NS (NHS)
19	Low Tunnel	20	LT (LT)
21	Walk-in Tunnel	22	WT (PWT)
23	High Plastic Shelter	24	PS (PHS)
25	Shade house	26	SH (NWT)

1553

1554 Codes for systems:

27	System	28	code
29	Soil without recycling	30	SnoR (SO-NWS)
31	Soil with recycling	32	S+R (SO-RWS)
33	Soilless without recycling	34	SLnoR (SL-NWS)
35	Soilless with recycling	36	SL+R (SL-RWS)

1555

1556 Codes for applications:

37	Application	38	code[#]
39	Through Irrigation System	40	DI (IRS)
41	Fogging or Fumigation	42	FogFum (FOF)
43	Soil Injection	44	Inj (SIN)
45	Spraying of the crop	46	Spray (SPR)
47	Soil Treatment	48	SoilAp (STR)

1557 [#] Abbreviations in brackets are according to EFSA (2011)

1558 Codes for emission routes:

Emission route	Code*
Spray drift emission at the moment of application	E1
Gas phase emission at the moment of application	E2
Gas phase emission during compulsory ventilation prior to re-entry	E3
Long-term gas phase emission through uncontrolled openings	E4
Long-term gas phase emission through regulated openings	E5
Leaching	E6
Discharge from tank	E7
Discharge of rinse water	E8
Discharge of condensation (controlled)	E9
Discharge of condensation (uncontrolled)	E10
Run-off from soil	E11
Removal of yield / non-yield biomass	E12
Removal of growing media	E13
Removal of plastic	E14

1559 * Emission routes E1 - E5 are emissions to air, E6 - E10 emissions to water and E11 (run-off) to water and / or soil.
 1560 Emissions E12 - E14 are emissions with solid waste or as harvested product, which will not be considered further.
 1561

FURTHER CHARACTERISATION OF CONSTRUCTION TYPES, APPLICATION TECHNIQUES AND EMISSIONS

EFSA (2010) provided systems for categorising different types of protected structures (see also Table B1), application techniques (see also Textbox 1) and growing systems (EFSA, 2010, Table 2).

Table B0.1: Classification criteria and main categories of protection structures

	Accessibility ^(a)	Temporary structure	Permeable cover ^(b)
Low plastic tunnel	No	Yes	No
(High) Plastic shelter	Yes	Yes	No
(High) Net shelter	Yes	Yes/No	Yes (net)
Shade house	Yes	Yes/No	Yes (net)
Walk-in tunnel	Yes	Yes	No
Greenhouse	Yes	No	No

^(a)Accessibility for operators; ^(b) permeable to water

Textbox 1: Application techniques

Irrigation system: (DI), PPP are applied through irrigation water drippers in open growing systems or into the recirculating water in closed-loop soilless systems.

Fogging: (FogFum), high pressure nozzles or high air speed are used to atomise the PPP solution in fine particles (less than 10 microns) producing a mist.

Fumigation: (FogFum), this method refers to canned chemicals that have a vaporising agent (or heat may be used) and are opened in closed walk-in structures for pest control.

Soil injection: (Inj), PPP (usually disinfectant) is brought into the soil with special equipment, before sowing or planting, at a certain depth (mixing of soil and PPP may occur afterwards).

Soil treatment: (SoilAp), PPP is sprayed onto the soil and mixed through the soil immediately after application.

Spraying: (Spray), an application of a PPP solution at low to high pressure through atomising nozzles onto the foliage of plants or the soil surface. The size of the spray droplets is such that most of the droplets will settle fairly quickly (by gravity).

1585

1586 **Table B2:** Short description of emission routes

– <i>E1 - Emission of spray droplets from the covered crop system.</i> As droplets will either evaporate (becoming then gas emission) or fall down, drift emission may take place only for a relatively short time after application. – <i>E2 - gas phase emission at moment of application</i> In terms of time scale, this emission route is quite similar to the previous one. Here air is the carrier instead of the droplets. – <i>E3 - gas-phase emission during compulsory ventilation prior to re-entry</i> This emission route refers to ventilation that takes place in order to remove the pesticide from the greenhouse air, after application. For most PPP this is a compulsory practice prior to re-entry of the personnel into the greenhouse. – <i>E4 - long-term gas phase emission through uncontrolled openings</i> Residues arising from deposition following volatilisation are a new exposure term under Directive 91/414 and are distinct from spray drift. This is called long-term, since deposited material will evaporate in days or even weeks. As the openings are non-regulated or only partly regulated, the ventilation rate is determined primarily by the wind speed. – <i>E5 - long-term gas phase emission through regulated openings</i> This is similar to the previous, only different by the fact that the openings are automatically regulated. – <i>E6 - leaching</i> Leaching of PPPs may occur after application of the substance to a soil-bound cropping system. In addition, leaching may occur after a spray application to a soilless cultivation if part of the applied PPP reaches the soil underlying the system (provided the floor of the system is not watertight). The term ‘leaching’ is used only to indicate (downward) passage of water and substance through soil. – <i>E7 - discharge from tank</i> This emission route typically goes along with a soilless cultivation system. A PPP that is contained in the nutrient solution is discharged to surface water or a sewage water treatment plant along with surplus nutrient solution. This emission route mostly will occur in glasshouses or greenhouses, but occasionally also in walk-in tunnels. – <i>E8 - discharge of rinse water</i> This emission route is possible in all construction types having a waste water tank. Cleansing water originates from cleaning filtration systems and rinsing substrates, but also from scrubbing the floor and cleaning the (glass) cover. Such emission will therefore mostly occur in glasshouses. – <i>E9 - discharge of condensation (controlled)</i> Discharge of condensation occurs in construction types equipped with a collection system for condensation water. In some countries, e.g. the Netherlands, such a collection system is statutory for glasshouses. Condensation water may contain PPPs because of exchange processes with the air in the system. – <i>E10 - discharge of condensation (uncontrolled)</i> If a collection system for condensation water is not installed, as e.g. is the case in low tunnels and walk-in tunnels, the condensation water is emitted in an uncontrolled way. Condensation water usually flows to the soil, which (partly) has to be considered as not being part of the covered crop system. – <i>E11 - run-off</i> Overland flow of water, possibly containing PPP, to soil or surface water outside the covered crop system.	
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– *E12 - Removal of yield / non-yield biomass*

Harvested products may still contain residues of PPP. Also plants remnants may contain residues. Removal of harvested products and remnants from the construction may thus constitute an emission.

– *E13 - Removal of growing media*

Any substrate (rockwool, perlite, compost, ...), removed from the construction at or after harvest possibly contains residues of PPP and thus is a potential emission source.

– *E14 - Removal of plastic*

Plastic covers may have been exposed to PPP and still contain remnants when they are removed from the system.

1587

1588

EXTRACTION FROM THE EFSA DATABASE ON PROTECTED STRUCTURES

****The reader should be aware that ppm (1 m² per 100 ha) is sometimes used and that the scale in some figures is logarithmic. ****

This appendix gives some details and examples on the occurrence of structures and crops grown in closed walk-in structures (i.e. walk-in tunnels and low- and high-tech greenhouses in Europe). The information is available in an EFSA database and can be used for amongst other development of scenarios for assessment of emissions from covered crops. All data are gathered for the most recent years after 2002, depending on the national surveys or sources. If possible the area was stratified up to regional level (NUTS 2 level). More information is available in the database, which is too detailed to be covered in this appendix

DATA COLLECTIONS ON AREA WITH CROPS UNDER PROTECTED STRUCTURES IN EUROPE

First step to harmonize the European information on area with crops under protected structures was the definition of a common classification of the structures, the crops under consideration and the characteristics of the structures and the growing practices.

Protection structures were classified into 13 categories by stepwise refinement. Small structures are normally summarized together with growing on open fields. More information is given on large, walk-in structures. While open walk-in structures consist on high shelters and shade houses, closed walk-in structures describe large and/or permanent structures, like walk-in tunnels, greenhouses and closed buildings. We distinguish between low and high technology greenhouses depending on their equipment of climate control, ventilation etc. Closed buildings are mainly used for cultivation of mushrooms or witloof.

A hierarchical approach is also used to classify the protected crops. Main groups are: fruits; leafy, fruity and other vegetables; cut flowers, pot ornamentals and propagation material. Most information is collected on the basis of mayor crops, like Solanacea – tomatoes, cucurbits with edible peel – cucumbers or all kind of salads, as representatives of their class.

All data are gathered for the most recent years after 2002, depending on the national surveys or sources. If possible the area was stratified up to regional level of NUTS 2 level

This report will provide an overview on the existing information which were obtained and can be used to define scenarios for the evaluation of pesticide use in protected crop structures. The given examples are selected to discuss the usefulness of the approach, but they are not complete. Detailed information can be found in the reports on the individual data collections (Sas Paszt *et al.* 2010, Sigrimis *et al.* 2010, EFSA 2011) or finally in the database on European acreage with crop protection structures.

Main results with use in scenario selection

Summarizing these activities EFSA got an overview on large and/or permanent crop protection structures in Europe, namely “Closed Walk-In Structures” and their sub categories. These structures may have the largest impact on the behaviour of pesticides in the environment and are therefore most important for this task.

Small and more open structures are mostly counted together with growing on the open field. This might be reasoned by the temporary use or to growing conditions more equal to open field conditions (growing in soil, unregulated ventilation, no climate control). To include small and open structures into the guidelines more information on typical agricultural practise in the different European countries has to be collected.

The following chapter will therefore focus on the acreage of four main crops / crop groups protected by “Closed Walk-In Structures”:

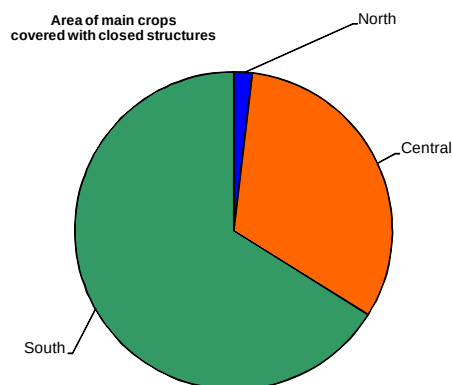
- 1634 • Solanacea, including tomatoes, peppers, aubergines
- 1635 • Cucurbits with edible peel, including cucumbers
- 1636 • Lettuce
- 1637 • Cut flowers and pot ornamentals

1638 Because of the importance of these crops for cultivation in greenhouses we found more or less
 1639 complete information in whole Europe. Detailed information on specific crops of these groups or other
 1640 crops might be reported by some member states, but is more scattered.

1641 Growing of fruits, esp. strawberries and table grapes, in protected structures is common as well.
 1642 Unfortunately the growing practises are mixed between closed walk-in structures and small
 1643 (strawberries) or open (table grapes) structures. Therefore these crops are less suited for the use as
 1644 example in this report.

1645 **Total acreage and overview**

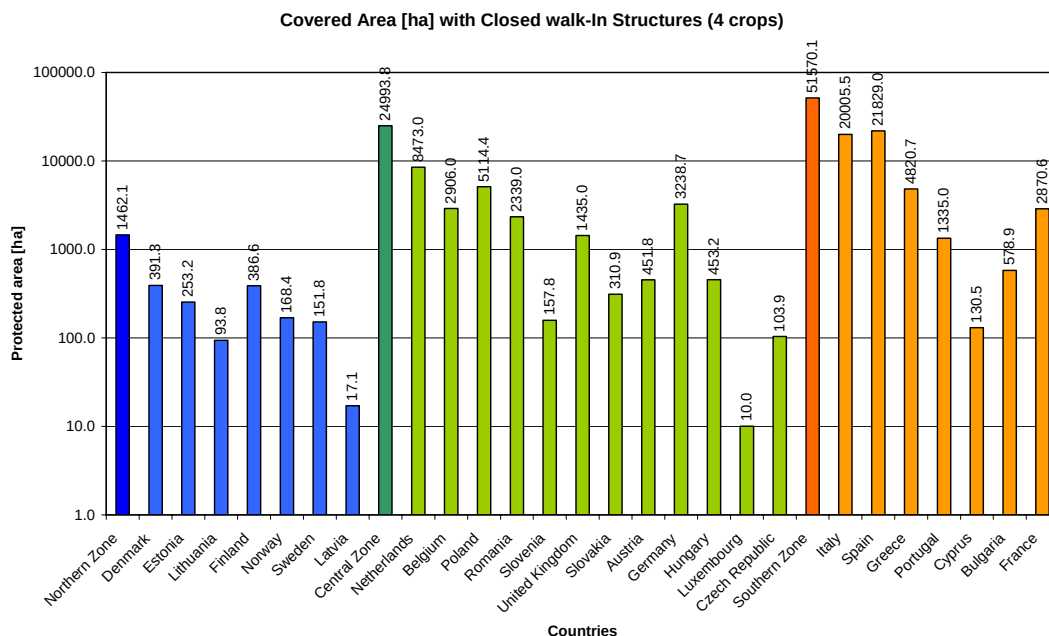
1646 Regarding the selected four crops more than 78000 ha of growing area are covered with closed
 1647 walk-in structures in Europe. Most of these structures are located in the southern zone (66% = 51570
 1648 ha). Only 2% (= 1462 ha) can be found in the Northern zone.



1649

1650 **Figure C1** Distribution of the area of main crop groups under closed walk-in structures for the
 1651 European zones.

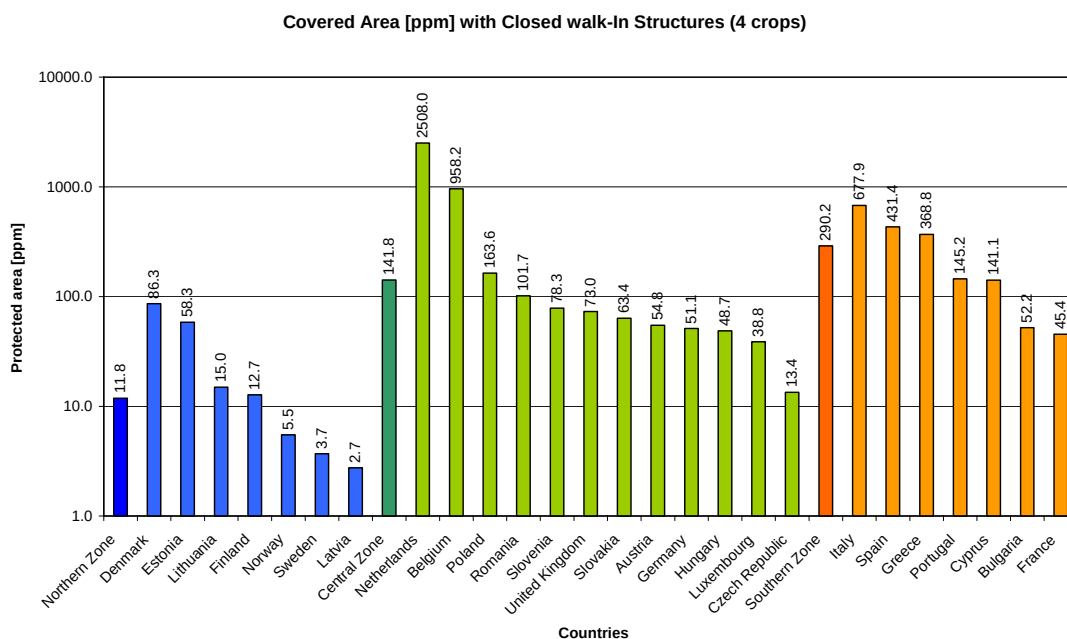
1652 Spain has most covered area, followed by Italy and the Netherland. Due to possible lacking
 1653 information the figures for minor countries are more uncertain than for the major ones. No information
 1654 was available for Malta, Ireland, Switzerland, Iceland and Liechtenstein.



1655

1656 **Figure C2** Area of main crop groups under closed walk-in structures for the European countries in
1657 hectare (logarithmic scale).

1658 To estimate relevant emissions to the environment the total covered area is less important than the part
1659 of the total land area, which is covered. We express this part in “ppm” (parts per million) or 1 m²
1660 closed walk-in structure per 100 ha land area of a country.



1661

1662 **Figure C3** Density of closed walk-in structures (for main crop groups) for the European countries in
1663 parts per million (ppm, logarithmic scale).

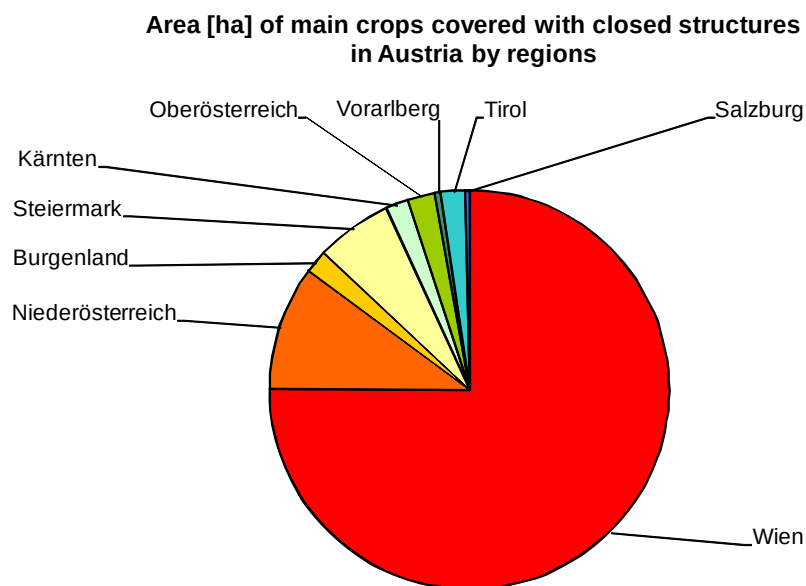
1664 Regarding the density of closed structures in Europe the ranking between the countries is changed.
1665 The Netherlands are leading with 2500 ppm before Belgium (958 ppm), Italy (678 ppm) and Spain
1666 (431 ppm).

1667 Regional information is only available for some countries, mostly on a province level (NUTS2
1668 classes). We selected for each zone two countries: the country per zone with the highest density:
1669 Denmark (North), Netherlands (Central) and Italy (South) and the next important country with
1670 available information on a regional scale (Finland, Austria, Greece). Details can be found in the
1671 attached tables.

1672 **Regional information**

1673 This analysis shows big variations within each country. Growing under closed walk-in structures is
1674 mainly clustered in the European countries. Reasons might be a production close to high populated
1675 areas (capital areas, like in Austria), good infrastructures (transportation etc., like in the Netherlands)
1676 or favourable climatic conditions (like in Italy).

1677 Three fourth of the covered area in Austria is located close to the capital Vienna



1678

1679 **Figure C4** Distribution of the area of main crop groups under closed walk-in structures for the
1680 regions of Austria.

1681 Regarding the density the Vienna region has about a factor of 100 more intensive protected culture of
1682 solanacea then all other regions.

1683

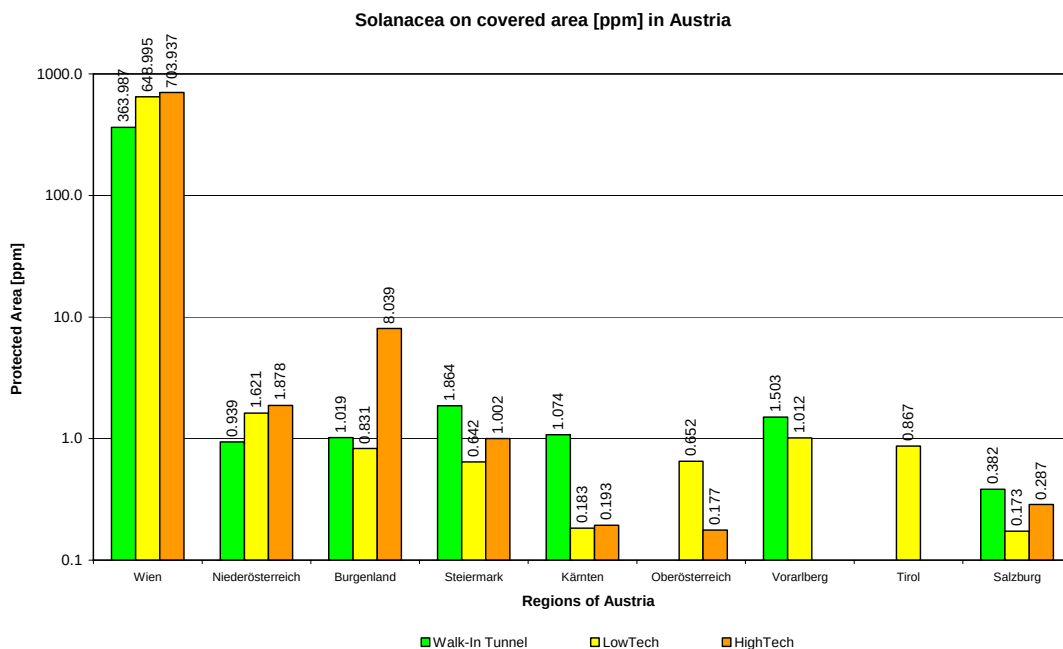


Figure C5 Density of different closed walk-in structures for Solanacea in different regions of Austria in parts per million (ppm, logarithmic scale).

In the Netherlands covered area is mostly located in the South-West with a focus in the glasshouse district (Westland) in South-Holland (Zuid-Holland). More than 50% of the covered area (of main crops) is located here.

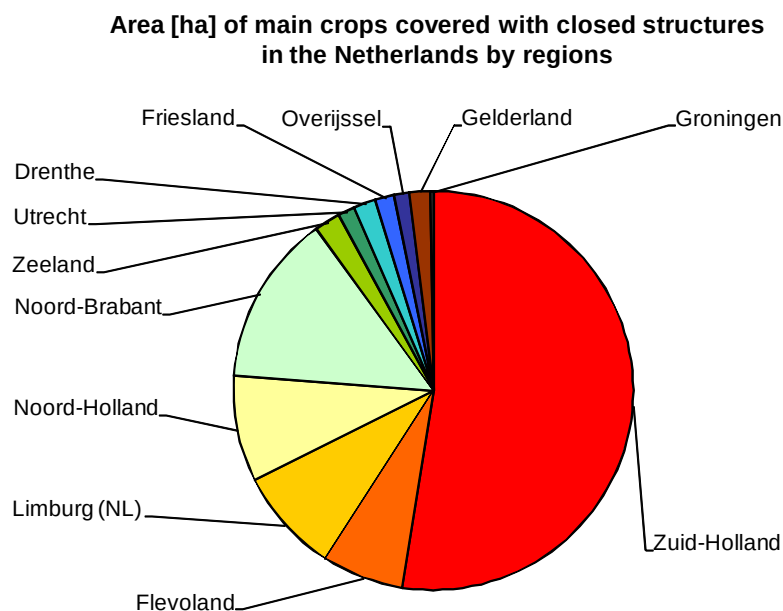
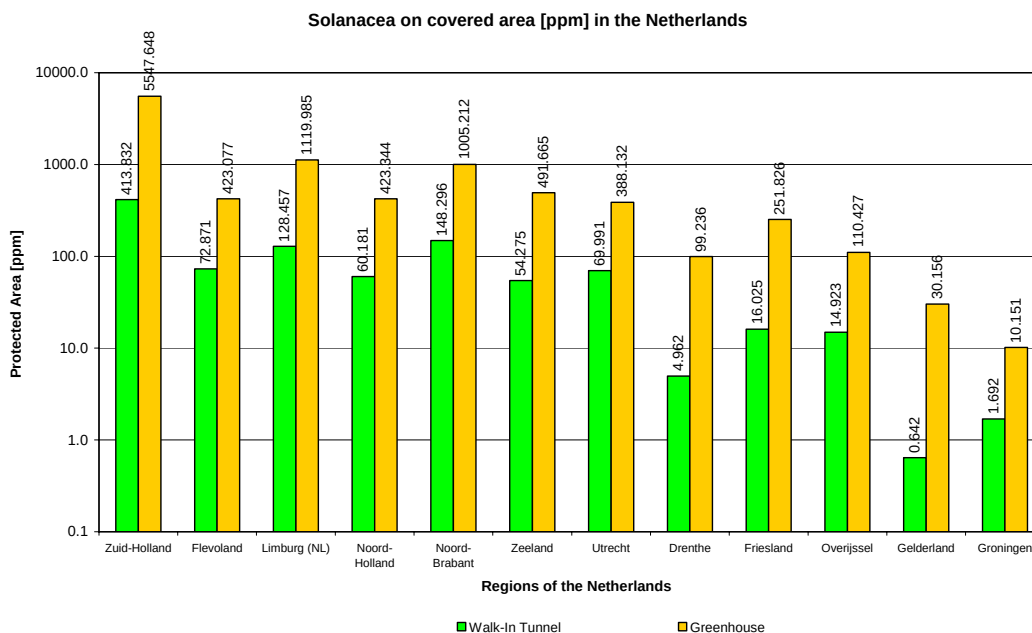


Figure C6 Distribution of the area of main crop groups under closed walk-in structures for the regions of the Netherlands

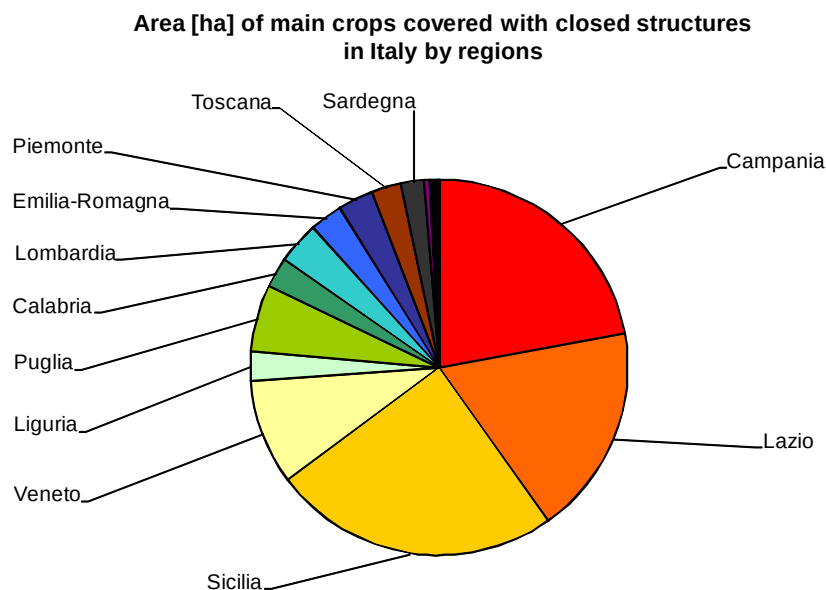
1693 The density of production of e.g. Solanacea is a factor of 5 to 10 higher in South-Holland than in the
1694 neighbouring provinces. Similar results exists for the other crops, like cucurbits and cut flowers



1695

1696 **Figure C7** Density of different closed walk-in structures for Solanacea in different regions of the
1697 Netherlands in parts per million (ppm, logarithmic scale).

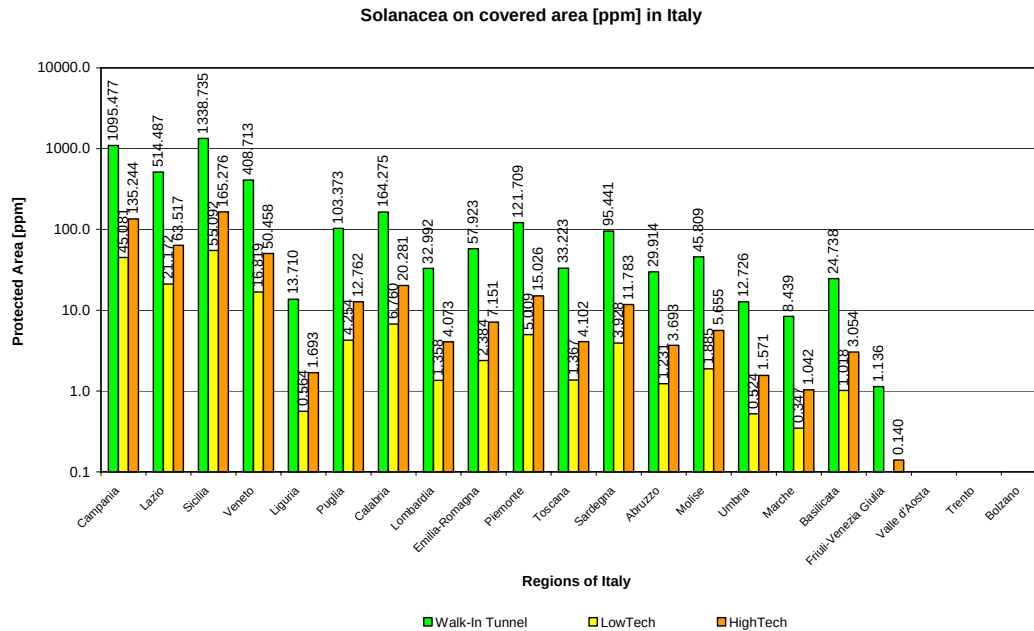
1698 Most of the covered area of Italy can be found around Rom (Lazio, Calabria) and on Sicily with about
1699 two thirds of the acreage for the main crops.



1700

1701 **Figure C8** Distribution of the area of main crop groups under closed walk-in structures for the
1702 regions of Italy

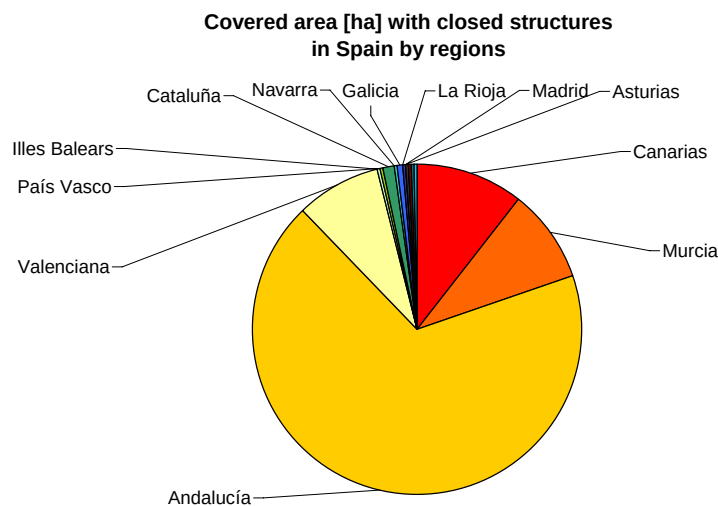
1703



1704

1705 **Figure C9** Density of different closed walk-in structures for Solanacea in different regions of Italy in
1706 parts per million (ppm, logarithmic scale).

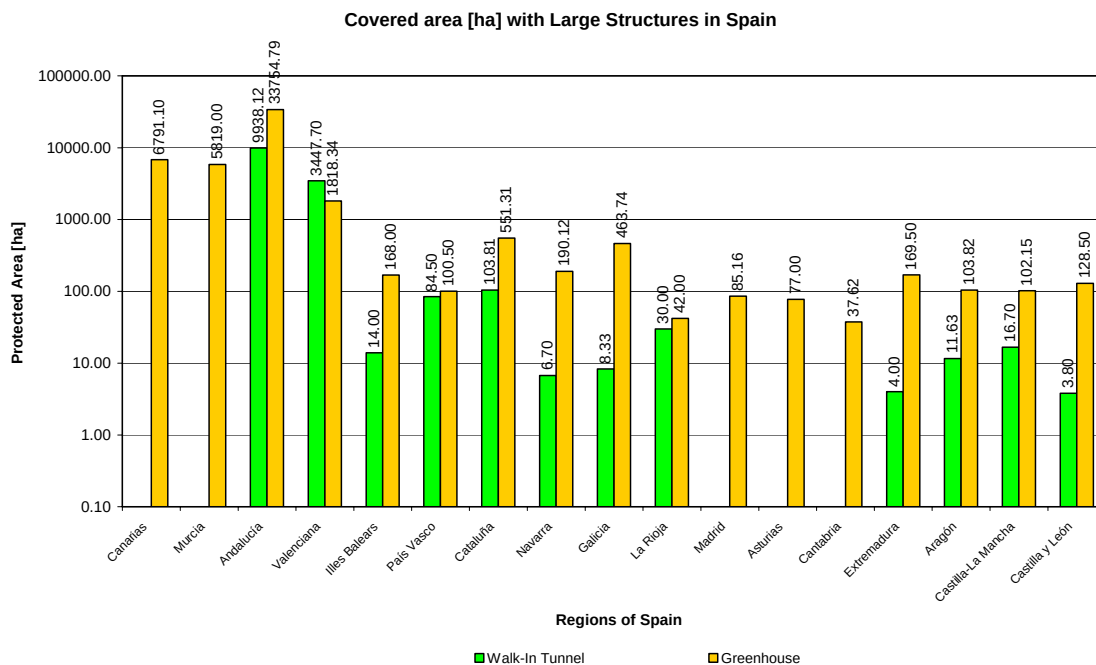
1707 The Spanish data don't differentiate between different crops, but greenhouses are mainly located to the
1708 coastal area of Almeria (about 60%), Murcia and Granada in the South-East of the Iberian Peninsula,
1709 and the Canary Islands. (Sigrimis *et al.*, 2010). The majority of covered area (near 90%) is used for
1710 growing vegetables, the rest is dedicated for flowers, ornamentals and fruits (Sigrimis *et al.*, 2010).



1711

1712 **Figure C10** Distribution of the area under closed walk-in structures for the regions of Spain (Sigrimis
1713 *et al.*, 2010)

1714 Regarding the regional distribution in Spain the density on the Canary Islands is comparable to the
1715 South-West provinces of the Netherlands.



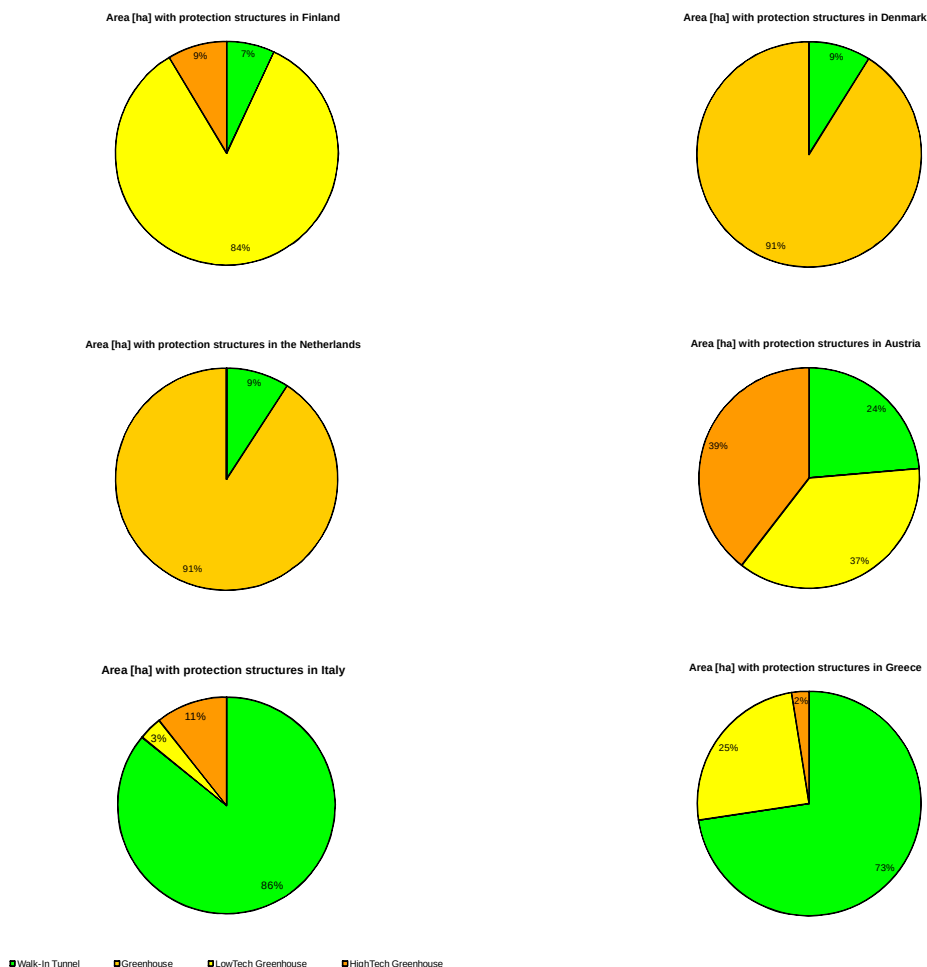
1716

1717 **Figure C11** Density of different closed walk-in structures for Solanacea in different regions of Spain
1718 in parts per million (ppm, logarithmic scale) (Sigrimis *et al.*, 2010).

1719 The type of the protection structure is mainly connected with the economic value of the covered crop,
1720 but information on the typical growing practise for specific crops is seldom available from official
1721 statistical offices. Additional the percentage of more simple structures (walk-in tunnels) is higher in
1722 the Southern zone then in the Northern due to the climatic conditions.

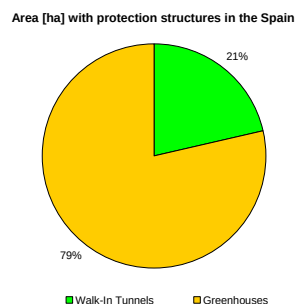
1723

1724



1725 **Figure C12** Distribution of the area of main crop groups under different closed walk-in structures for
1726 some European countries of different zones.

1727 The Spanish data include all covered crops and are more similar to the Northern and Central profile.



1728

1729 **Figure C13** Distribution of the area of main crop groups under different closed walk-in structures for
1730 Spain (Sigrimis *et al.*, 2010)

1731

Crop specific information

We selected four crop groups to illustrate the crop profile of the countries: Solanacea (main crops are tomatoes), cucurbits with edible peel (main crops are cucumbers, all kind of salad and cut flowers/pot ornamentals. Cut flowers and pot ornamentals dominating in the Northern and Central zone, while Solanacea are more grown under protection in the Southern zone. But the country profiles are varying widely.

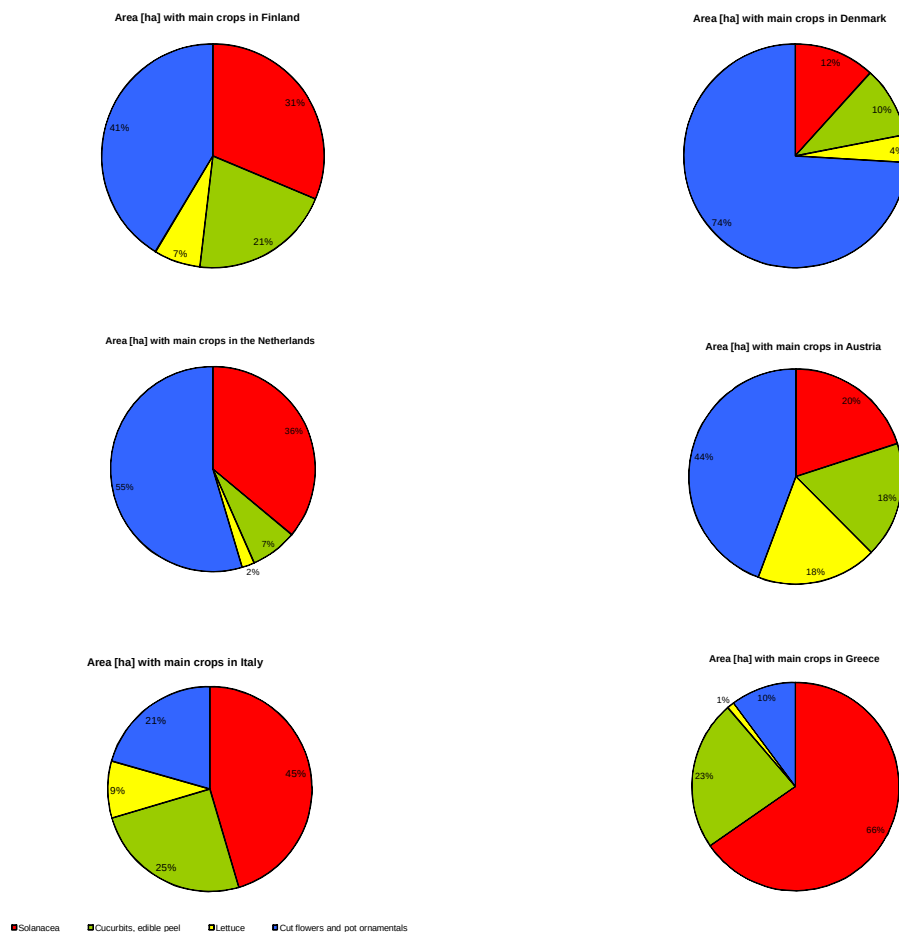
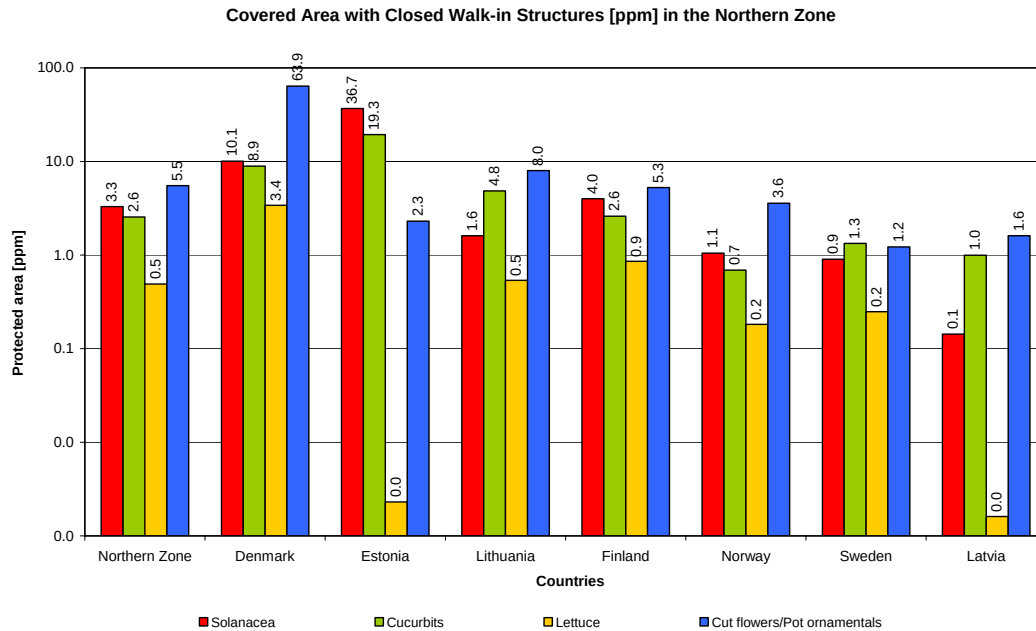


Figure C14 Distribution of the area of different main crop groups under closed walk-in structures for some European countries of different zones

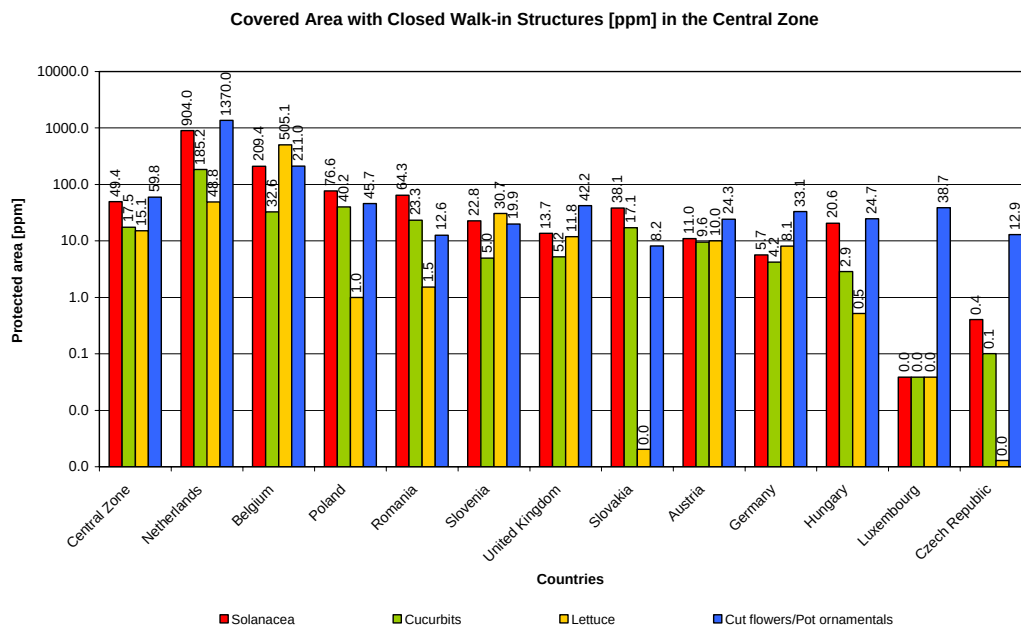
1742



1743

1744 **Figure C15** Density of different main crop groups under closed walk-in structures in European
1745 countries of the Northern zone in parts per million (ppm, logarithmic scale).

1746



1747

1748 **Figure C16** Density of different main crop groups under closed walk-in structures in European
1749 countries of the Central zone in parts per million (ppm, logarithmic scale).

1750 The same diversity can be noticed within a single country. Some regions are specialised to specific
1751 crops. As examples we zoom in into Austria, the Netherlands and Italy.

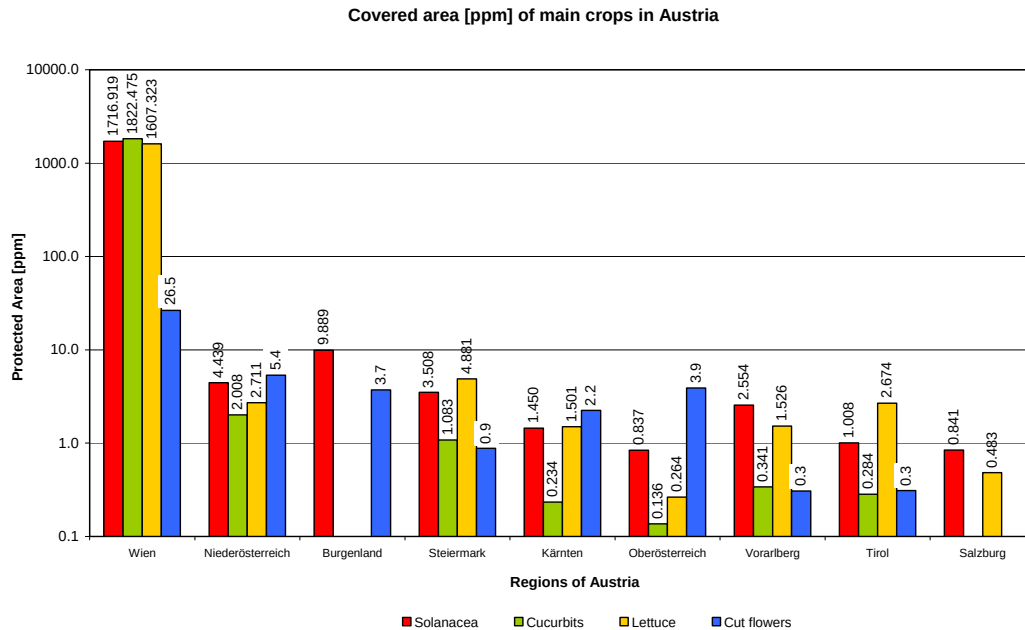


Figure C17 Density of different main crop groups under closed walk-in structures in different regions of Austria in parts per million (ppm, logarithmic scale).

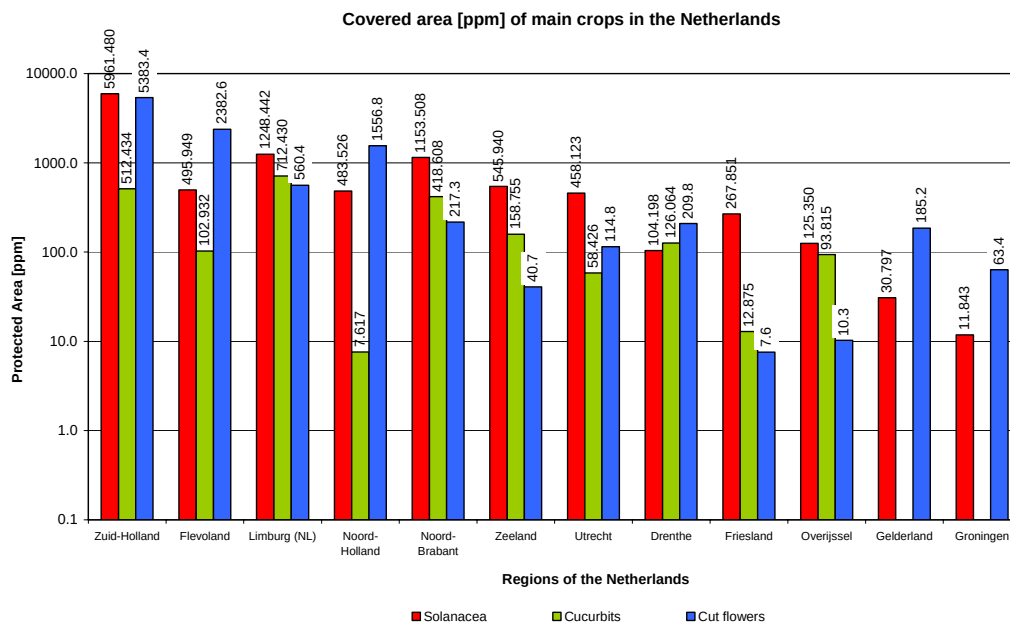
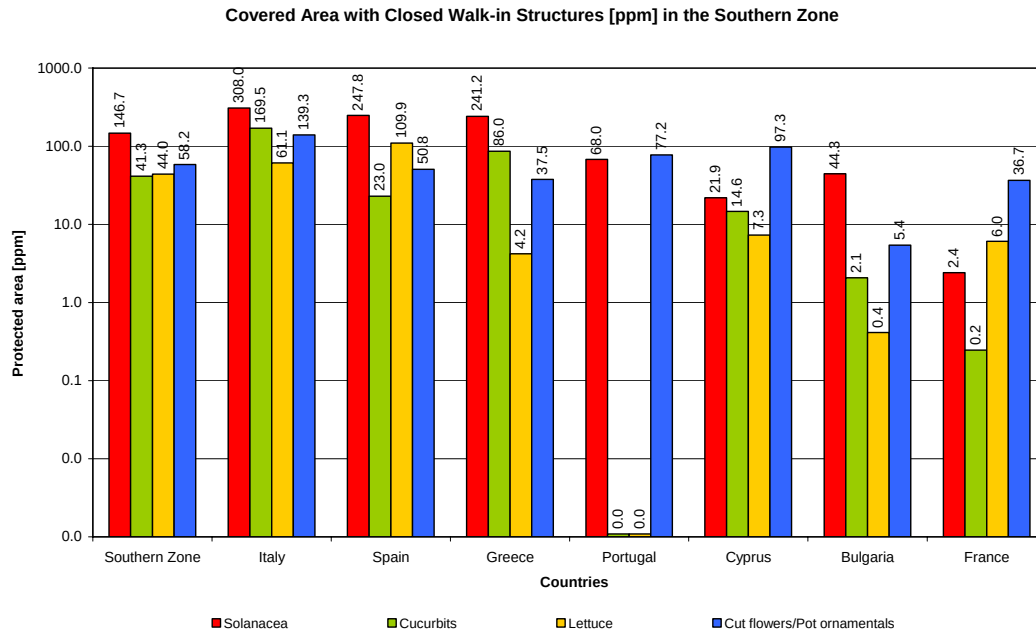


Figure C18 Density of different main crop groups under closed walk-in structures in different regions of the Netherlands in parts per million (ppm, logarithmic scale).

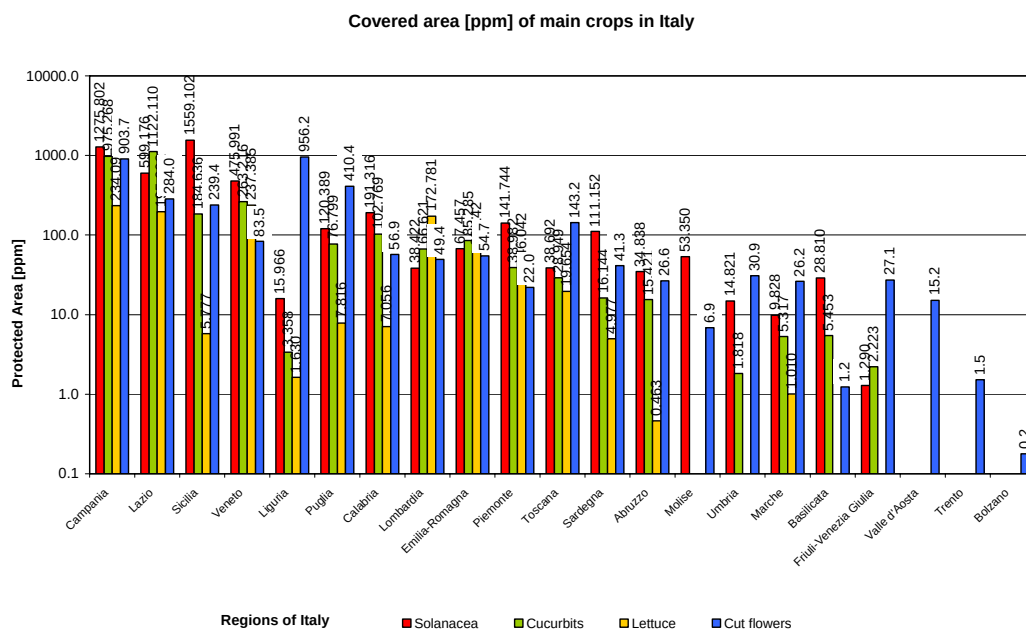
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1762 **Figure C19** Density of different main crop groups under closed walk-in structures in European
 1763 countries of the Southern zone in parts per million (ppm, logarithmic scale).

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1766 **Figure C20** Density of different main crop groups under closed walk-in structures in the regions of
 1767 Italy in parts per million (ppm, logarithmic scale).

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Tables

Table C1: Areas of closed walk-in structures in the 27 countries of the EU as well as in the three regulatory zones (EFSA database).

Country	Total area [ha] of Closed Walk-In Structures					Land area [km ²]	Density [ppm] of Closed Walk-In Structures				
	Sum	Solanacea	Cucurbits, edible peel	Lettuce	Cut flowers and pot ornaments		Sum	Solanacea	Cucurbits, edible peel	Lettuce	Cut flowers and pot ornaments
	[ha]	[ha]	[ha]	[ha]	[ha]		[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Northern Zone	1462.1	406.4	315.8	60.6	679.3	1234786.1	11.8	3.3	2.6	0.5	5.5
Denmark	391.3	45.8	40.3	15.4	289.8	45348.58	86.3	10.1	8.9	3.4	63.9
Estonia	253.2	159.2	84.0	0.0	10.0	43432	58.3	36.7	19.3	0.0	2.3
Lithuania	93.8	10.1	30.3	3.4	50.0	62678	15.0	1.6	4.8	0.5	8.0
Finland	386.6	121.240	79.2	26.110	160.0	304472.5	12.7	4.0	2.6	0.9	5.3
Norway	168.4	32.2	21.1	5.6	109.5	306252	5.5	1.1	0.7	0.2	3.6
Sweden	151.8	37.0	54.6	10.2	50.0	410313	3.7	0.9	1.3	0.2	1.2
Latvia	17.1	0.9	6.2	0.0	10.0	62290	2.7	0.1	1.0	0.0	1.6
Central Zone	24993.8	8708.7	3089.8	2660.1	10535.2	1762263.1	141.8	49.4	17.5	15.1	59.8
Netherlands	8473.0	3053.9	625.7	165.0	4628.3	33783.6	2508.0	904.0	185.2	48.8	1370.0
Belgium	2906.0	635.0	99.0	1532.0	640.0	30328	958.2	209.4	32.6	505.1	211.0
Poland	5114.4	2395.9	1257.3	31.2	1430.0	312685	163.6	76.6	40.2	1.0	45.7
Romania	2339.0	1478.0	536.0	35.0	290.0	229954	101.7	64.3	23.3	1.5	12.6
Slovenia	157.8	45.9	10.0	61.9	40.0	20141	78.3	22.8	5.0	30.7	19.9
United Kingdom	1435.0	269.0	103.0	233.0	830.0	196708.4	73.0	13.7	5.2	11.8	42.2
Slovakia	310.9	186.9	84.0	0.0	40.0	49034	63.4	38.1	17.1	0.0	8.2
Austria	451.8	90.6	78.8	82.5	200.0	82459	54.8	11.0	9.6	10.0	24.3
Germany	3238.7	358.6	268.5	514.7	2096.9	634284.5	51.1	5.7	4.2	8.1	33.1
Hungary	453.2	191.7	26.7	4.9	230.0	93031	48.7	20.6	2.9	0.5	24.7
Luxembourg	10.0	0.0	0.0	0.0	10.0	2586	38.8	0.0	0.0	0.0	38.7
Czech Republic	103.9	3.1	0.8	0.0	100.0	77268.6	13.4	0.4	0.1	0.0	12.9
Southern Zone	51570.1	26068.2	7339.4	7812.5	10350.0	1776856.1	290.2	146.7	41.3	44.0	58.2
Italy	20005.5	9090.1	5001.0	1804.4	4110.0	295113	677.9	308.0	169.5	61.1	139.3
Spain	21829.0	12536.7	1162.9	5559.5	2570.0	505997	431.4	247.8	23.0	109.9	50.8
Greece	4820.7	3152.5	1123.5	54.7	490.0	130714	368.8	241.2	86.0	4.2	37.5
Portugal	1335.0	624.9	0.0	0.0	710.0	91946.7	145.2	68.0	0.0	0.0	77.2
Cyprus	130.5	20.3	13.5	6.8	90.0	9250	141.1	21.9	14.6	7.3	97.3
Bulgaria	578.9	491.3	23.0	4.6	60.0	111001.9	52.2	44.3	2.1	0.4	5.4
France	2870.6	152.4	15.6	382.6	2320.0	632833.5	45.4	2.4	0.2	6.0	36.7

1774 **Table C2: Areas of closed walk-in structures and main crop groups in the six European countries of the regulatory zones (EFSA database)**

1775 **Finland (Northern zone)**

NUTS Code	Region	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
FI00	Finland	6.7		104.7	9.9	6.0		66.5	6.8	3.1		20.7	2.3	2.5		28.8	3.6
FI19	Länsi-Suomi	2.0		78.9	7.4	1.1		37.4	3.9	0.5		4.8	1.0	0.4		7.5	1.3
FI18	Etelä-Suomi	4.4		21.9	1.8	4.6		25.1	2.2	2.6		13.9	1.1	2.0		18.8	2.0
FI20	Åland	0.0		0.3	0.0	0.0		0.3	0.0	0.0		0.0	0.0	0.0		0.1	0.0
FI13	Itä-Suomi	0.2		3.5	0.6	0.2		3.7	0.6	0.0		2.0	0.2	0.1		2.4	0.3

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Region	Land area	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[km²]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Finland	304472.5	0.2		3.4	0.3	0.2		2.2	0.2	0.1		0.7	0.1	0.1		0.9	0.1
Länsi-Suomi	58275.9	0.4		13.5	1.3	0.2		6.4	0.7	0.1		0.8	0.2	0.1		1.3	0.2
Etelä-Suomi	40796.6	1.1		5.4	0.4	1.1		6.2	0.5	0.6		3.4	0.3	0.5		4.6	0.5
Åland	1526.5	0.1		2.1	0.2	0.1		1.7	0.2	0.0		0.0	0.0	0.0		0.3	0.0
Itä-Suomi	70294.6	0.0		0.5	0.1	0.0		0.5	0.1	0.0		0.3	0.0	0.0		0.3	0.0

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1779 **Denmark (Northern zone)**

NUTS Code	Region	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
DK00	Denmark	4.2	41.6			3.5	36.8			1.4	14.0			0.6	6.0		
DK02	Sjælland	3.1	23.4			2.5	18.3			1.2	8.5			0.4	2.7		
DK03	Fyn	0.7	15.1			0.7	16.0			0.2	5.3			0.1	2.6		
DKZZ	Jylland	0.3	3.2			0.3	2.5			0.0	0.2			0.1	0.7		

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Region	Land area	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
	[km²]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Denmark	45348.58	0.9	9.2			0.8	8.1			0.3	3.1			0.1	1.3		
Sjælland	9624.48	3.3	24.3			2.6	19.0			1.2	8.9			0.4	2.8		
Fyn	12206.17	0.6	12.4			0.6	13.1			0.2	4.3			0.1	2.1		
Jylland	21057.66	0.2	1.5			0.1	1.2			0.0	0.1			0.0	0.3		

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1785 **1. The Netherlands (Central zone)**

NUTS Code	Region	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
NL00	Netherlands	275.4	2778.5			64.3	561.4							243.3	2446.8		
NL33	Z-Holland	116.6	1563.4			10.0	134.4							105.3	1411.8		
NL23	Flevoland	10.3	60.0			2.1	12.5							49.7	288.5		
NL42	Limburg	27.7	241.1			15.8	137.6							12.4	108.2		
NL32	N-Holland	16.1	113.0			0.3	1.8							51.7	364.0		
NL41	N-Brabant	73.0	494.5			26.5	179.5							13.7	93.1		
NL34	Zeeland	9.7	87.9			2.8	25.6							0.7	6.5		
NL31	Utrecht	9.7	53.8			1.2	6.9							2.4	13.5		
NL13	Drenthe	1.3	26.2			1.6	31.7							2.6	52.8		
NL12	Friesland	5.4	84.3			0.3	4.1							0.2	2.4		
NL21	Overijssel	5.0	36.7			3.7	27.5							0.4	3.0		
NL22	Gelderland	0.3	15.0			0.0	0.0							1.9	90.2		
NL11	Groningen	0.4	2.4			0.0	0.0							2.1	12.7		

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Region	Land area	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[km²]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Netherlands	33783.6	81.5	822.4			19.0	166.2							72.0	724.2		
Z-Holland	2818.1	413.8	5547.6			35.6	476.9							373.7	5009.7		
Flevoland	1419.3	72.9	423.1			15.1	87.8							350.1	2032.5		
Limburg	2153.1	128.5	1120.0			73.3	639.1							57.7	502.7		
N-Holland	2670.4	60.2	423.3			0.9	6.7							193.8	1363.0		
N-Brabant	4919.3	148.3	1005.2			53.8	364.8							27.9	189.3		
Zeeland	1788.1	54.3	491.7			15.8	143.0							4.0	36.6		
Utrecht	1386.2	70.0	388.1			8.9	49.5							17.5	97.3		
Drenthe	2642	5.0	99.2			6.0	120.1							10.0	199.8		
Friesland	3349.3	16.0	251.8			0.8	12.1							0.5	7.1		
Overijssel	3326.7	14.9	110.4			11.2	82.6							1.2	9.1		
49 Gelderland	50 497 5.1	51 0.6	52 30.2	53	54	55 0.0	56 0.0	57	58	59	60	61	62	63 3.9	64 181.3	65	66
67 Groningen	68 233 6	69 1.7	70 10.2	71	72	73 0.0	74 0.1	75	76	77	78	79	80	81 9.1	82 54.4	83	84

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1789 **2. Austria (Central zone)**

NUTS Code	Region	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
AT00	Austria	21.4		32.5	36.7	17.4		29.6	31.8	20.5		30.9	31.0	5.3		7.5	8.4
AT13	Wien	14.4		25.7	27.9	15.3		27.3	29.6	13.5		24.1	26.1	0.2		0.4	0.4
AT12	Niederösterreich	1.8		3.1	3.6	0.8		1.4	1.6	1.1		1.9	2.2	2.7		4.1	3.3
AT11	Burgenland	0.4		0.3	3.0	0.0		0.0	0.0	0.0		0.0	0.0	0.4		0.1	0.9
AT22	Steiermark	3.0		1.0	1.6	0.9		0.3	0.5	4.2		1.5	2.3	0.3		0.4	0.7
AT21	Kärnten	1.0		0.2	0.2	0.2		0.0	0.0	1.0		0.2	0.2	0.7		0.7	0.7
AT31	Oberösterreich	0.0		0.8	0.2	0.0		0.1	0.0	0.0		0.2	0.1	1.0		1.5	2.1
AT34	Vorarlberg	0.4		0.3	0.0	0.1		0.0	0.0	0.2		0.2	0.0	0.0		0.0	0.1
AT33	Tirol	0.1		1.1	0.1	0.0		0.3	0.0	0.3		2.9	0.1	0.0		0.2	0.2
AT32	Salzburg	0.3		0.1	0.2	0.0		0.0	0.0	0.2		0.1	0.1	0.0		0.0	0.0

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Region	Land area	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[km ²]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Austria	82459	2.6		3.9	4.4	2.1		3.6	3.9	2.5		3.7	3.8	0.6		0.9	1.0
Wien	396	364.0		649.0	703.9	386.4		688.9	747.2	340.8		607.6	659.0	6.3		10.6	9.7
Niederösterreich	18929	0.9		1.6	1.9	0.4		0.7	0.8	0.6		1.0	1.1	1.4		2.2	1.7
Burgenland	3681	1.0		0.8	8.0	0.0		0.0	0.0	0.0		0.0	0.0	1.0		0.3	2.5
Steiermark	16247	1.9		0.6	1.0	0.6		0.2	0.3	2.6		0.9	1.4	0.2		0.3	0.4
Kärnten	9364	1.1		0.2	0.2	0.2		0.0	0.0	1.1		0.2	0.2	0.7		0.8	0.7
Oberösterreich	11724	0.0		0.7	0.2	0.0		0.1	0.0	0.0		0.2	0.1	0.8		1.3	1.8
Vorarlberg	2536	1.5		1.0	0.0	0.3		0.2	0.0	0.9		0.6	0.0	0.1		0.0	0.2
Tirol	12529	0.1		0.9	0.0	0.0		0.3	0.0	0.3		2.3	0.1	0.0		0.1	0.2
Salzburg	7053	0.4		0.2	0.3	0.1		0.0	0.0	0.2		0.1	0.2	0.0		0.0	0.1

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1794 **3. Italy (Southern zone)**

NUTS Code	Region	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
IT00	Italy	7805.2		321.2	963.6	4294.2		176.7	530.1	1549.4		63.8	191.3	3987.6		164.1	492.3
ITF3	Campania	1467.1		60.4	181.1	1121.5		46.2	138.5	269.2		11.1	33.2	1039.1		42.8	128.3
ITE4	Lazio	869.3		35.8	107.3	1628.0		67.0	201.0	283.9		11.7	35.0	412.1		17.0	50.9
ITG1	Sicilia	3401.6		140.0	419.9	402.8		16.6	49.7	12.6		0.5	1.6	522.4		21.5	64.5
ITD3	Veneto	718.1		29.6	88.7	397.1		16.3	49.0	358.2		14.7	44.2	126.1		5.2	15.6
ITC3	Liguria	7.3		0.3	0.9	1.5		0.1	0.2	0.8		0.0	0.1	437.6		18.0	54.0
ITF4	Puglia	198.4		8.2	24.5	126.6		5.2	15.6	12.9		0.5	1.6	676.2		27.8	83.5
ITF6	Calabria	242.4		10.0	29.9	130.2		5.4	16.1	8.9		0.4	1.1	72.1		3.0	8.9
ITC4	Lombardia	75.2		3.1	9.3	130.4		5.4	16.1	338.3		13.9	41.8	96.6		4.0	11.9
ITD5	Emilia-Romagna	124.7		5.1	15.4	157.6		6.5	19.5	116.7		4.8	14.4	101.0		4.2	12.5
ITC1	Piemonte	302.6		12.5	37.4	83.2		3.4	10.3	98.3		4.0	12.1	46.9		1.9	5.8
ITE1	Toscana	75.3		3.1	9.3	56.3		2.3	7.0	38.2		1.6	4.7	278.7		11.5	34.4
ITG2	Sardegna	228.0		9.4	28.2	33.1		1.4	4.1	10.2		0.4	1.3	84.7		3.5	10.5
ITF1	Abruzzo	31.8		1.3	3.9	14.1		0.6	1.7	0.4		0.0	0.1	24.3		1.0	3.0
ITF2	Molise	20.0		0.8	2.5	0.0		0.0	0.0	0.0		0.0	0.0	2.6		0.1	0.3
ITE2	Umbria	10.5		0.4	1.3	1.3		0.1	0.2	0.0		0.0	0.0	21.9		0.9	2.7
ITE3	Marche	8.1		0.3	1.0	4.4		0.2	0.5	0.9		0.0	0.1	21.5		0.9	2.7
ITF5	Basilicata	24.0		1.0	3.0	4.6		0.2	0.6	0.0		0.0	0.0	1.0		0.0	0.1
ITD4	Friuli-Venezia Giulia	0.9		0.0	0.1	1.4		0.1	0.2	0.0		0.0	0.0	17.6		0.7	2.2
ITC2	Valle d'Aosta	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	4.2		0.2	0.5
ITD2	Trento	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.8		0.0	0.1
ITD1	Bolzano	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.1		0.0	0.0

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Region	Land area	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
	[km ²]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Italy	295113	264.5		10.9	32.7	145.5		6.0	18.0	52.5		2.2	6.5	135.1		5.6	16.7
Campania	13392	1095.5		45.1	135.2	837.4		34.5	103.4	201.0		8.3	24.8	775.9		31.9	95.8
Lazio	16897	514.5		21.2	63.5	963.5		39.7	119.0	168.0		6.9	20.7	243.9		10.0	30.1
Sicilia	25409	1338.7		55.1	165.3	158.5		6.5	19.6	5.0		0.2	0.6	205.6		8.5	25.4
Veneto	17571	408.7		16.8	50.5	226.0		9.3	27.9	203.8		8.4	25.2	71.7		3.0	8.9
Liguria	5330	13.7		0.6	1.7	2.9		0.1	0.4	1.4		0.1	0.2	821.1		33.8	101.4
Puglia	19191	103.4		4.3	12.8	65.9		2.7	8.1	6.7		0.3	0.8	352.4		14.5	43.5
Calabria	14753	164.3		6.8	20.3	88.2		3.6	10.9	6.1		0.2	0.7	48.9		2.0	6.0
Lombardia	22800	33.0		1.4	4.1	57.2		2.4	7.1	148.4		6.1	18.3	42.4		1.7	5.2
Emilia-Romagna	21523	57.9		2.4	7.2	73.2		3.0	9.0	54.2		2.2	6.7	46.9		1.9	5.8
Piemonte	24860	121.7		5.0	15.0	33.5		1.4	4.1	39.5		1.6	4.9	18.9		0.8	2.3
Toscana	22657	33.2		1.4	4.1	24.9		1.0	3.1	16.9		0.7	2.1	123.0		5.1	15.2
Sardegna	23892	95.4		3.9	11.8	13.9		0.6	1.7	4.3		0.2	0.5	35.4		1.5	4.4
Abruzzo	10635	29.9		1.2	3.7	13.2		0.5	1.6	0.4		0.0	0.0	22.9		0.9	2.8
Molise	4373	45.8		1.9	5.7	0.0		0.0	0.0	0.0		0.0	0.0	5.9		0.2	0.7
Umbria	8252	12.7		0.5	1.6	1.6		0.1	0.2	0.0		0.0	0.0	26.5		1.1	3.3
Marche	9554	8.4		0.3	1.0	4.6		0.2	0.6	0.9		0.0	0.1	22.5		0.9	2.8
Basilicata	9719	24.7		1.0	3.1	4.7		0.2	0.6	0.0		0.0	0.0	1.1		0.0	0.1
Friuli-Venezia Giulia	7556	1.1		0.0	0.1	1.9		0.1	0.2	0.0		0.0	0.0	23.3		1.0	2.9
Valle d'Aosta	3239	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	13.0		0.5	1.6
Trento	6140	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	1.3		0.1	0.2
Bolzano	7370	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.2		0.0	0.0

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1800 **4. Greece (Southern zone)**

NUTS Code	Region	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
		[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]
GR00	Greece	2294.7		759.8	98.0	808.2		304.6	10.7	43.7		11.0	0.0				
GR43	Kriti	1487.5		36.9	32.8	505.2		35.1	1.0	0.0		0.0	0.0				
GR12	Kentriki Makedonia	389.5		144.9	10.0	81.3		67.7	4.0	12.0		6.0	0.0				
GR30	Attiki	0.0		56.1	32.6	0.2		32.1	5.2	0.0		1.0	0.0				
GR25	Peloponnisos	148.8		171.6	4.9	81.0		89.3	0.0	5.0		0.2	0.0				
GR23	Dytiki Ellada	115.0		72.9	2.0	48.0		14.3	0.0	25.4		0.6	0.0				
GR21	Ipeiros	62.5		101.0	0.5	18.3		21.6	0.5	0.6		0.5	0.0				
GRZZ	Aigaio	36.1		44.2	2.0	60.0		24.3	0.0	0.0		1.7	0.0				
GR22	Ionia Nisia	8.2		6.6	0.7	1.8		1.7	0.0	0.2		0.0	0.0				
GR14	Thessalia	31.0		68.3	1.9	8.5		6.0	0.0	0.0		0.0	0.0				
GR11	Anatoliki Makedonia, Thraki	14.7		30.4	10.6	3.4		10.5	0.0	0.3		0.9	0.0				
GR24	Stereia Ellada	0.0		24.1	0.0	0.0		1.1	0.0	0.0		0.0	0.0				
GR13	Dytiki Makedonia	1.4		2.8	0.0	0.5		0.9	0.0	0.2		0.1	0.0				

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Region	Land area	Solanacea				Cucurbits, edible peel				Lettuce				Cut flowers			
		Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse	Walk-In Tunnel	Greenhouse	LowTech Greenhouse	HighTech Greenhouse
	[km ²]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Greece	130714	175.6		58.1	7.5	61.8		23.3	0.8	3.3		0.8	0.0				
Kriti	8335	1784.6		44.3	39.4	606.1		42.1	1.2	0.0		0.0	0.0				
Kentriki Makedonia	18884	206.3		76.7	5.3	43.1		35.9	2.1	6.4		3.2	0.0				
Attiki	3806	0.0		147.4	85.7	0.5		84.3	13.7	0.0		2.6	0.0				
Peloponnisos	15474	96.2		110.9	3.2	52.3		57.7	0.0	3.2		0.1	0.0				
Dytiki Ellada	11040	104.2		66.0	1.8	43.5		13.0	0.0	23.0		0.5	0.0				
Ipeiros	9076	68.9		111.3	0.6	20.2		23.8	0.6	0.7		0.6	0.0				
Aigaio	9109	39.6		48.5	2.2	65.9		26.7	0.0	0.0		1.9	0.0				
lonia Nisia	2297	35.7		28.7	3.0	7.8		7.4	0.0	0.9		0.0	0.0				
Thessalia	14004	22.1		48.8	1.4	6.1		4.3	0.0	0.0		0.0	0.0				
Anatoliki Makedonia, Thraki	14034	10.5		21.7	7.6	2.4		7.5	0.0	0.2		0.6	0.0				
Stereia Ellada	15435	0.0		15.6	0.0	0.0		0.7	0.0	0.0		0.0	0.0				
Dytiki Makedonia	9220	1.5		3.0	0.0	0.5		1.0	0.0	0.2		0.1	0.0				

1804