Emissions of plant protection products to groundwater from use in protected crops

VAN BEINUM W.[1], BEULKE S.[1], GARRATT J.A.[2], SAPOUNAS A.A.[3], VAN OS E.A.[3], VOOGT W.[3], PARDOSSI A.[4]
1 - The Food and Environment Research Agency (Fera), Sand Hutton, YO411LZ, York, UK
2 - Enviresearch, Herschel Building, Newcastle University, NE17RU, Newcastle upon Tyne, UK
3 - Wageningen UR, Greenhouse Horticulture, P.O. Box 9101, 6700 HB, Wageningen, THE NETHERLANDS
4 - University of Pisa, Viale Delle Piagge, 23, 56124 Pisa, ITALY
E-mail wendy.vanbeinum@fera.gsi.gov.uk

The PPR Panel of EFSA is evaluating the importance of emission routes to facilitate the development of risk assessment methodology for protected crops (crops grown under cover). To support this activity, EFSA commissioned a project to calculate emissions of plant protection products (PPP) from protected crops to air, groundwater and surface water for various combinations of cover structures and growing systems (EFSA, 2011). The results of this project are given here and in accompanying contributions.

The use of large amounts of irrigation water is common in certain types of soil-bound greenhouse cultivation to control the salinity level of the soil. Movement of excess water and associated PPP to depth may pose a risk to groundwater. Modelling was carried out to investigate whether emissions to groundwater from covered crops may exceed those from outdoor use in field crops. The location Venlo (Netherlands) was selected to represent a common situation in the central zone. Venlo has free draining sandy soils with a ground water table of ~1.5-2.5 m. Two crops with contrasting temperature optima (lettuce and chrysanthemum) and irrigation at 15% or 50% above the crop evapotranspiration, applied at 2 – 3 days (summer) to 7 days (winter) intervals, were considered in the model simulations. A PPP with a DT50 value of 100 days and a sorption Kom value of 116 L/kg was used in the modelling. The PPP was applied at 1 kg/ha on 30 April in each of 20 years. Additional PPP details were tested for the lettuce scenario with 50% irrigation excess (Kom 10, 20, 35, 60, 116 or 200 L/kg, DT50 10, 20, 60, 100, 150 or 200 days, application 30 April, 10 June or 1 August). The models KASPRO (de Zwart, 1996) and WATERSTROMEN (Voogt and van Os, 2011) were used to simulate the climate and water balance inside the greenhouse. The movement of the PPPs to below 1 m depth was calculated with FOCUS PEARL 3_3_3 (Leistra et al., 2001). Simulations were also undertaken for a generic crop in the field. Average annual rainfall in the field was 867 mm per year, in comparison with irrigation of 1060 mm per year in lettuce and 1245 mm per year in chrysanthemum for the greenhouse scenarios with 50% irrigation excess. The average temperature in the greenhouse was 18.1 °C for lettuce and 21.0 °C for chrysanthemum, while the average outside air temperature in the field was 10.7 °C.

The simulated annual volume of percolation below 1 m depth was less variable in the greenhouse than in the field (Figure 1). The average percolation over 20 years for the 50% excess irrigation scenarios was similar to that in the field. Table 1 shows the 80th percentile concentrations in groundwater for the five scenarios. The concentrations much were smaller for the greenhouse scenarios than for the field.

Figure 1 - Simulated annual average percolation in the field and greenhouse

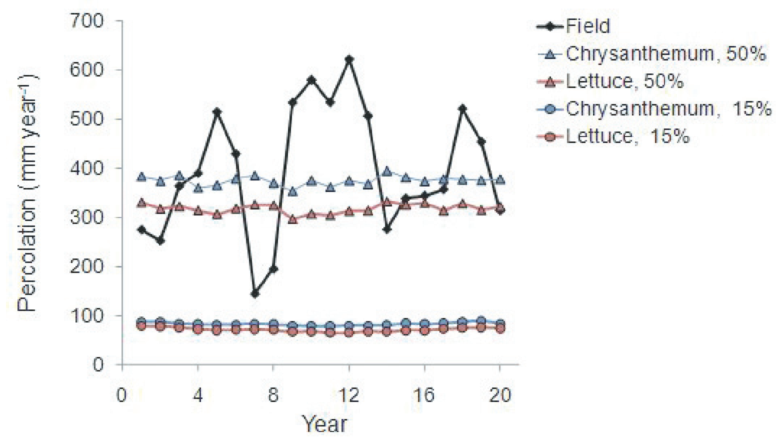
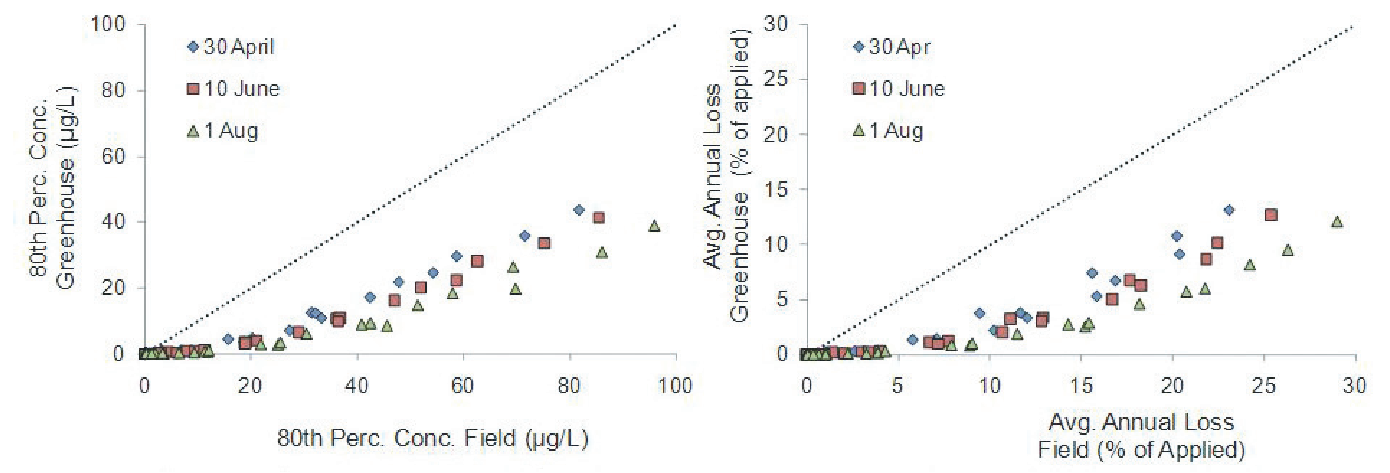


Table 1 - Simulated 80th percentile concentrations in groundwater

Scenario	80th Perc. Conc. (ug L-1)
Field	1.634
Chrysanthemum 50% excess	0.011
Lettuce 50% excess	0.035
Chysanthemum 15% excess	<0.001
Lettuce 15% excess	0.002

The key drivers for leaching are the volumes of leaching (influenced by the type of crop, length of cropping period and irrigation regime) and the temperature (influenced by the type of crop and the growing strategy, the cover structure and its control systems and the outside climate). The simulated 80th percentile concentrations in leachate for the lettuce scenario with 50% excess irrigation and the 108 combinations of application dates, sorption and degradation properties are plotted against those for the field in Figure 2. The average annual mass lost to below 1 m depth is also presented. The results show that emissions of PPPs to groundwater can be significant for protected crops (80th percentile concentrations above 0.1 µg L^{-1}). However, under the tested conditions, the calculated emissions to groundwater from the greenhouse were consistently smaller than those from the field (Figure 2). This is due to the higher temperature which led to faster dissipation in the greenhouse than in the field.

Figure 2 - 80th percentile concentrations (left) and annual mass loss to groundwater (right) for a range of substance properties and application dates. Results from the indoor lettuce scenario (50% excess) are plotted against the results from the field. The dotted line indicates exact agreement between the greenhouse and field



Simulations were only undertaken for a single location and a small number of crops. Simplifying assumptions were made to facilitate the comparison (e.g. possible enrichment with organic matter in the greenhouse and its effect on sorption and degradation was not considered). The uncertainties and limitations inherent in the assessment must be considered and additional model simulations are needed to test the validity of the conclusions drawn here for a wider range of conditions.

KEY WORDS: Pesticides, protected crops, greenhouse, risk assessment, leaching

Acknowledgements

The authors wish to thank EFSA for funding this work.

References

Beulke S., van Beinum W., Glass R., van Os E., Holterman, Sapounas, Voogt, van de Zande J., de Zwart F., 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 Regulation (EC) N° 1107/2009 and Council Directive 91/414/EEC. Scientific report to EFSA. Question no. EFSA-Q-2010-00830

De Zwart H.F. (1996). Analyzing energy-saving options in greenhouse cultivation using a simulation model. PhD dissertation, Wageningen University, 236 pp. ISBN 90-5485-533-9.

Leistra M., Van der Linden A.M.A., Boesten J.J.T.I., 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 of Public Health and the Environment. Wageningen, Alterra Green Research. RIVM report 711401009/Alterra-rapport 013. 116 pp.

Voogt W., Van Os E.A. (2011) Managing chemical water quality related problems in closed hydroponic systems. Acta Hort. 2011 (in press).