Science of the Total Environment 505 (2015) 670–679

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Volatilisation of pesticides after application in vegetable greenhouses

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HIGHLIGHTS

- Pesticides were found in greenhouse air for up to four days after application.
- Crop penetration and degradation of the substance compete with volatilisation.
- Vapour pressure, ventilation rate and temperature are important influencing factors.

ARTICLE INFO

Article history:
Received 20 August 2014
Received in revised form 10 October 2014
Accepted 10 October 2014
Available online xxxx

Editor: E. Capri

Keywords:
Greenhouses
Vegetables
Air concentration
Measurements
Pesticide residue

ABSTRACT

Background: Volatilisation of pesticides after application to the soil or the crop is an important source of emission into the atmosphere. As a result, workers, residents and bystanders are potentially at risk when exposed to these volatilised substances. Nonetheless, data on measured concentrations are quite scarce, especially in greenhouses. The objective of this work is to present the results of volatilisation experiments performed in greenhouses.
Results: The results indicate that the concentrations are highest in the hours after application and rapidly decline during the days following application.
Conclusion: Greenhouse temperature, ventilation rate, the substance vapour pressure and the rate of competing processes were identified as important factors influencing volatilisation in greenhouses. The results from this study contribute to a better understanding of volatilisation in greenhouses and may help to improve the recent PEARL model for volatilisation in greenhouses.

1. Introduction

In agriculture and horticulture, crop protection products are applied to the soil or crop to safeguard the quality and yield of the crop by protecting it from harmful organisms and diseases. It has been acknowledged for many years that volatilisation of the applied substance during and after application may be a substantial source of emission into the atmosphere. In the past, many studies have been dedicated to quantifying the emission of pesticides from the soil or plant into the air. Overviews of the available volatilisation rate data demonstrate that the observed volatilisation rates range from 0% of the applied dose to more than 90% for very volatile substances such as lindane (Bedos et al., 2002; Guth et al., 2004; Smit et al., 1997, 1998). The degree of volatilisation is highly variable because it not only depends on the physicochemical properties of the substance, but also on the prevailing meteorological conditions and the processes taking place in and on the soil or crop (Bedos et al., 2002; van den Berg et al., 1999).

From a health perspective, research on the volatilisation of pesticides after application is valuable as inhalation of the volatilised pesticides may result in adverse health effects of those exposed. The emission of pesticides into the air poses a risk for persons living or working in the vicinity of the treated crops as well as for those engaged in re-entry activities in the treated area. From this point of view, greenhouses can be considered as worst-case scenarios. Because greenhouses are closed environments, pesticide concentrations tend to be higher in comparison with those measured in open fields. The ventilation rate of a greenhouse plays a crucial role as this parameter indicates how often the air inside the greenhouse is changed. Higher ventilation rates lower the concentration of volatilised pesticides inside the greenhouse and hence reduce the risk for workers at work inside the greenhouse. However, higher ventilation rates also result in higher emissions into the outdoor air where bystanders and residents in turn may be exposed.

Many studies have focused on volatilisation from the soil, because soil-applied fumigants are often highly volatile and are therefore a major source of emission into the atmosphere (van den Berg et al., 1999).

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http://dx.doi.org/10.1016/j.scitotenv.2014.10.036
0048-9697/

Nonetheless, studies have indicated that volatilisation from plants may be higher because pesticides adsorb less to plants than to soil (Bedos et al., 2002; Guth et al., 2004). Other studies report that the more complex nature of the leaf surface results in a more turbulent air flow above the leaves which in its turn favours volatilisation from the plants (Rüdel, 1997). Furthermore, the higher volatilisation rates from plants can to some extent be attributed to the larger exchange surface provided by plants in comparison to soil. Still, research on volatilisation from plants, especially in greenhouses, is scarce (e.g. Brouwer et al., 1992; Siebers and Mattusch, 1996). In recent years however, there has been an increasing interest in this topic, including from the European Food Safety Authority (Beulke et al., 2011; EFSA, 2010).

In the past, the PEARL model (Pesticide Emission Assessment at Regional and Local scales) has been developed to simulate the volatilisation process from plant surfaces under outdoor conditions (Leistra et al., 2001; van den Berg and Leistra, 2004). Recently, the PEARL model was extended to include volatilisation from plant surfaces under greenhouse conditions. This extended model can be used to estimate the concentrations of the volatilised substances in the greenhouse air and can thus be used to assess the inhalation exposure of workers engaged inside the greenhouses for a wide range of substances. An important step in the development of any model is the testing phase, where model simulations are compared with experimental data. Data from published studies on the volatilisation of plant protection products from plants under greenhouse conditions are quite scarce and often cannot be used to test the extended PEARL model due to the data requirements for the model. The model not only requires data on influencing factors such as the ventilation rate and the greenhouse dimensions, but also requires hourly greenhouse climate data to be able to simulate the fate of the substance after its application. As a result, the data from currently published studies are inadequate to test and help improve the extended PEARL model.

This paper presents the results of experiments on the volatilisation of plant protection products performed in glasshouses in Belgium. The concentration of the plant protection products in the greenhouse air was measured with active air sampling after application. Air sampling took place after application to bare soil and to greenhouse crops (cucumber and tomato). This study was aimed at improving the current knowledge of the volatilisation process from plant surfaces in greenhouses by studying the effect of the air ventilation rate, air temperature, measurement height, location within the greenhouse, substance properties and competing processes on the measured concentrations in the greenhouse air. In the meantime, a complete and comprehensive dataset was developed that can be used to test and improve the recent PEARL model for estimating greenhouse concentrations of plant protection products.

2. Material and methods

2.1. Greenhouses and crops

The volatilisation experiments were conducted in the greenhouse complex of the Research Station for Vegetable Production (RSVP) in Sint-Katelijne-Waver, Belgium. According to the EFSA classification system of protected structures, the RSVP greenhouses are classified as high-technology greenhouses of the "Venlo" type with an automatic climate control system (EFSA, 2010). Greenhouse temperature, relative humidity and window opening were measured and registered on an hourly basis with a Hortimax climate control system fitted with Ektron-II C sensors. Greenhouses with three different crop types were used for this study: lettuce, tomato and cucumber. The lettuce crop was grown in a soil-bound system, whereas the tomato and cucumber crops were grown in a gutter system with substrate. The greenhouse characteristics can be found in Fig. 1 and Table 1.

2.2. Ventilation rates

Two types of ventilation regimes were used during the course of the experiments. During experiments 1 and 4, ventilation of the greenhouse was controlled by the climate control system, based on temperature measurements inside the greenhouse. This system aimed at creating an optimal microclimate for the crop by maintaining an optimal growing temperature (e.g. 20 °C for tomatoes) by opening the greenhouse vents. Ventilating the greenhouses also helped to reduce the relative humidity inside the greenhouses and hence the risk for diseases. During experiments 2 and 3, the climate control system was overruled and all windows were kept closed during and after application.

Ventilation rate experiments were conducted to determine the indicative values for the ventilation rates for different window openings. However, it is important to note that greenhouse ventilation rates not only depend on the greenhouse window opening but also on the outside wind speed, wind direction and on the temperature difference between the inside and the outside (Baptista et al., 1999; Boulard et al., 1997). It was beyond the scope of this study to perform a detailed ventilation rate study, so the ventilation rates were only determined for a single set of conditions. Hence, the ventilation rates obtained in this study should be considered as indicative values.

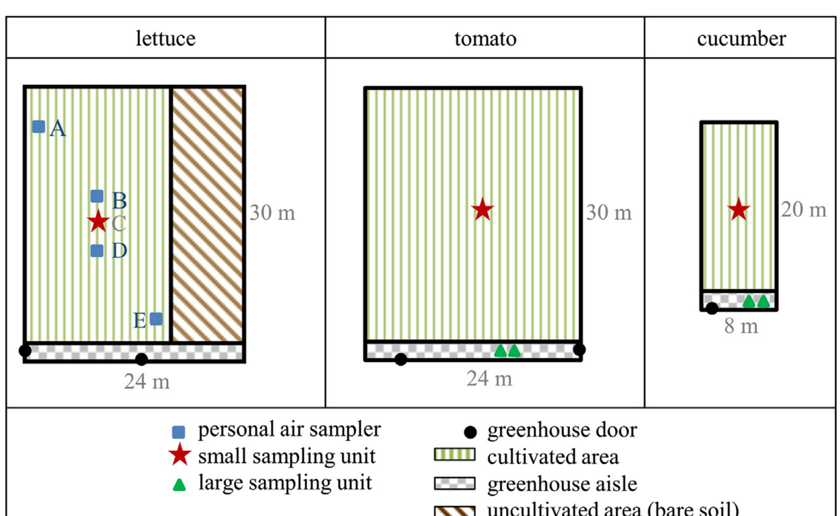

Fig. 1. Greenhouse lay-out with air sampling locations.