Science of the Total Environment 619–620 (2018) 874–882

Contents lists available at ScienceDirect

Science of the Total Environment

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

Assessment of exposure of professional agricultural operators to pesticides

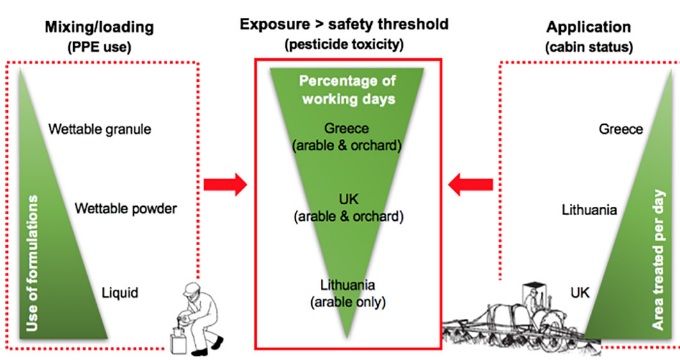
Hie Ling Wong [a,c,*], David G. Garthwaite [b], Carmel T. Ramwell [b], Colin D. Brown [a]

[a] Environment Department, University of York, York YO10 5NG, United Kingdom
[b] Fera Science Ltd (Fera), Sand Hutton, York YO41 1LZ, United Kingdom
[c] Faculty of Earth Science, University Malaysia Kelantan, Locked Bag 100, Jeli 17600, Kelantan, Malaysia

HIGHLIGHTS

- First use of comprehensive dataset for activities of professional pesticide operators
- Operator exposures compared for three countries and arable and orchard systems
- Small number of applications in all systems with estimated exposure > safety level
- Risks in Greece driven by use of wettable powder formulations
- Risks in the UK driven by large areas of land treated per day

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 16 September 2017
Received in revised form 10 November 2017
Accepted 11 November 2017
Available online xxxx

Editor: E. Capri

Keywords:
Plant protection product
Mixing/loading
Formulation
PPE
AOEM
Operator exposure

ABSTRACT

This study investigates how field practices in handling and applying pesticides influence the long-term patterns of professional agricultural operators' exposure to pesticides. It presents the first use of a comprehensive pesticide application dataset collected on behalf of the European Food Safety Authority with 50 operators selected to cover arable and orchard cropping systems in Greece, Lithuania and the UK. Exposure was predicted based on the harmonised Agricultural Operator Exposure Model (AOEM) and compared with Acceptable Operator Exposure Levels (AOELs). The amount of pesticides handled by individual operators across a cropping season was largest in the UK arable and orchard systems (median 580 and 437 kg active substance, respectively), intermediate for the arable systems in Greece and Lithuania (151 and 77 kg, respectively), and smallest in the Greek orchard system (22 kg). Overall, 30 of the 50 operators made at least one application within a day with predicted exposure greater than the AOEL. The rate of AOEL exceedance was greatest in the Greek cropping systems (8 orchard operators, 2.8–16% of total applications; 7 arable operators, 1.1–14% of total applications), and least for the Lithuanian arable system (2 operators, 2.9–4.5% of total applications). Instances in Greece when predicted exposure exceed the AOEL were strongly influenced by the widespread use of wettable powder formulations (>40% of the total pesticide active substance handled for 11 of the 20 Greek operators). In contrast, the total area of land treated with an active substance on a single day was more important in the UK and Lithuania (95th percentile observed value was 132 and 19 ha day^{-1} for UK arable and orchard systems, respectively). Study findings can be used to evaluate current assumptions in regulatory exposure calculations and to identify situations with potential risk that require further analysis including measurements of exposure to validate model estimations.

* Corresponding author at: Environment Department, University of York, York YO10 5NG, United Kingdom.
E-mail address: hw1166@york.ac.uk (H.L. Wong).

https://doi.org/10.1016/j.scitotenv.2017.11.127
0048-9697/

1. Introduction

Pesticides are widely used in agriculture to increase crop productivity and quality in order to meet the increasing demand for food from the world's growing population. Off-target movement of pesticides, however, may pose a risk to human health and the environment due to the intrinsic toxicity of this class of chemicals. Three major categories of human exposure to pesticides are identified, namely occupational, environmental, and dietary exposures (Mehrpour et al., 2014). Occupational exposure to pesticides is of particular interest in epidemiology because the exposure could be at levels hundreds of times greater than that for the general population (Sacchettini et al., 2015), and because this may cause excess risk for some diseases (Brouwer et al., 2016). For example, an association between occupational exposure and cancer was first reported around 50 years ago with higher prevalence of lung and skin cancers amongst farmers who used insecticides in vineyards (Mostafalou and Abdollahi, 2013). A review on the consequences of occupational exposure to pesticides on the male reproductive system proposed that the majority of pesticides could affect the system by mechanisms including reduction of sperm counts and density, inhibition of spermatogenesis, sperm DNA damage, and increasing abnormal sperm morphology (Mehrpour et al., 2014).

Agricultural operators are mainly exposed to pesticides during the preparation and application of the spray solution (Damalas and Abdollahzadeh, 2016). Due to spills and splashes, direct spray contact, or even drift, they are potentially exposed to pesticides via two routes of exposure, namely dermal absorption and respiratory inhalation (Gao et al., 2013; Moon et al., 2013; Ye et al., 2013; Damalas and Koutroubas, 2016). Whilst the dermal route is usually considered to constitute the major route of exposure to pesticides for agricultural operators (Zhao et al., 2015; Atabila et al., 2017), the inhalation route should not be neglected because of the presence of airborne spray droplets or vapour resulting from the spray preparation; the application could be dangerous as the lungs can rapidly absorb the dissolved pesticides into the bloodstream (Ogg et al., 2012; Choi et al., 2013). Generally, the operator is expected to engage in both mixing/loading and application tasks, and exposures via the dermal and inhalation routes arising from these tasks are summed to give the total potential exposure (EFSA, 2014).

The exposure of agricultural operators to pesticides could be influenced by a range of factors including the properties of the compound, agricultural factors (e.g. crop height, application equipment and technique), environmental factors (e.g. wind velocity and direction, temperature and relative humidity), protection measures, working behaviour, experience, and training (Aprea, 2012; Gao et al., 2013; Tsakirakis et al., 2014; Zhao et al., 2016). Generally, the levels of exposure during typical activities are predicted rather than measured due to complexities in measuring dose via different routes and limitations in biological monitoring together with the very wide range in climatic and working conditions that need to be considered (Colosio et al., 2012). Conventionally, the potential risk from human exposure to pesticide is expressed with a risk quotient which is the ratio of predicted exposure to a toxicological reference value that combines the risk with the amount and conditions of pesticide use (Cunha et al., 2012). Several predictive models are available to estimate operator exposure to pesticides including the EUROpean Predictive Operator Exposure Model (EUROPOEM), the UK Predictive Operator Exposure Model (UK POEM), the German Operator Exposure Model (German model), and the Bystanders, Residents, Operators, and WorkerS Exposure models (BROWSE) (Lammoglia et al., 2017).

Operator exposure must be estimated in the risk assessment for pesticides in accordance with EU Regulation (EC) 1107/2009 (Thouvenin et al., 2016). The exposure is normally estimated separately for mixing/loading and application tasks and for the recommended conditions of use (EFSA, 2014). Two operator exposure models were officially recommended by Regulation 1107/2009 for lower-tier risk assessment of agricultural operators to pesticides in the EU, namely the UK POEM (UK MAFF, 1992) and the German model (Lundehn et al., 1992; NASDA, 2013). These are deterministic models derived from statistical analysis of data from exposure studies conducted before 1990. They have been superseded by the newly developed Agricultural Operator Exposure Model (AOEM; Groβkopf et al., 2013a). The AOEM is the first harmonised European operator exposure model, relying on empirical data from 34 exposure studies (1994–2009) to reflect agricultural practices and scientific knowledge. Despite the large database used for model development, the AOEM has some data gaps including the lack of exposure data for knapsack mixing/loading and hand-held applications in low crops (Groβkopf et al., 2013b).

European Union Directive 91/414/EEC concerning the placement of plant protection products on the market required that application of plant protection products following good practice should have no harmful effects on human health and no unacceptable influence on the environment. Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures ensures that the intrinsic toxicological potential of hazardous products is clearly communicated to users in the EU for the necessity of protection measures (Lichtenberg et al., 2015). In performing risk assessments of exposure to plant protection products in the EU, the zonal approach has been introduced by Regulation (EC) 1107/2009 for the evaluation and registration of plant protection products by taking into account national agronomics and regional differences (i.e. environmental conditions and application techniques) (Tsakirakis et al., 2014). The wide diversity of agriculture throughout the EU including farming practices and farm size incurs some challenges for European policy-makers in making decisions (EPRS, 2016).

This study investigates how field practice in handling and applying pesticides influences exposure for professional agricultural operators. To do this we apply information from a European database of pesticide application practices where, for the first time, all pesticide handling activities across individual working days were quantified for a large number of individuals and over protracted periods of up to a full year (Garthwaite et al., 2015). We select individuals from different cropping systems and different regulatory zones (northern, central, southern) of the EU and applied the AOEM (Groβkopf et al., 2013a) to assess levels of exposure for professional operators. We analyse results to determine differences in behaviours and patterns of exposure with cropping, region and working practices, and compare exposures with Acceptable Operator Exposure Levels (AOELs) to investigate any implications for operator assessments within regulatory procedures.

2. Methodology

2.1. Pesticide application data

We used a dataset for pesticide application collected on behalf of the European Food Safety Authority (EFSA) in view of performing environmental risk assessments for pesticides in response to Regulation 1107/2009 (Garthwaite et al., 2015). The data were collected based on specifically designed survey forms in eight EU member states that together represent the three regulatory zones comprising Northern (Lithuania), Central (Belgium, Netherlands, Poland and United Kingdom) and Southern (Greece, Italy and Spain). Overall, the surveys collected information regarding >36,000 individual application events for operators on over 400 farms, with 645 sprayers used on nine different crops. A minimum of twenty fields were surveyed for each crop for between two and five crops in each member state, with at least two member states collecting information on each crop (Garthwaite et al., 2015).

We assessed the long-term patterns of professional agricultural operators' exposure to pesticides handled for Lithuania, the UK, and Greece to represent the three regulatory zones. These three member states were also the only ones that met the data quality requirements of our study with respect to finalised quality checking and data entry (Garthwaite et al., 2015). The temporal unit of assessment was whole working days in 2012–2013; the periods of data collection were