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Assessing human health risks from pesticide use in conventional and innovative cropping systems with the BROWSE model

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ABSTRACT

Background: Reducing the risks and impacts of pesticide use on human health and on the environment is one of the objectives of the European Commission Directive 2009/128/EC in the quest for a sustainable use of pesticides. This Directive, developed through European national plans such as Ecophyto plan in France, promotes the introduction of innovative cropping systems relying, for example, on integrated pest management. Risk assessment for human health of the overall pesticide use in these innovative systems is required before the introduction of those systems to avoid that an innovation becomes a new problem.

Objectives: The objectives of this work were to assess and to compare (1) the human exposure to pesticides used in conventional and innovative cropping systems designed to reduce pesticide needs, and (2) the corresponding risks for human health.

Methods: Humans (operator and residents) exposure to pesticides and risks for human health were assessed for each pesticide with the BROWSE model. Then, a method was proposed to represent the overall risk due to all pesticides used in one system. This study considers 3 conventional and 9 associated innovative cropping systems, and 116 plant protection products containing 89 different active substances (i.e. pesticides).

Results: The modelling results obtained with BROWSE showed that innovative cropping systems such as low input or no herbicide systems would reduce the risk for human health in comparison to the corresponding conventional cropping systems. On the contrary, BROWSE showed that conservation tillage system would lead to unacceptable risks in the conditions of our study, because of a high number of pesticide applications, and especially of some herbicides. For residents, the dermal absorption was the main exposure route while ingestion was found to be negligible. For operators, inhalation was also a predominant route of exposure. In general, human exposure to pesticides and human health risks were found to be correlated to the treatment frequency index TFI (number of registered doses of pesticides used per hectare for one copping season), confirming the relationship between the reduction of pesticide use and the reduction of risks.

Conclusions: Assessment with the BROWSE model helped to identify cropping systems with decreased risks from pesticides for human health and to propose some improvements to the cropping systems by identifying the pesticides that led to unacceptable risks.

1. Introduction

The European Commission Directive 2009/128/EC (2009) established a framework to achieve sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and on the environment, and by promoting the use of integrated pest management (IPM) or alternative approaches of pest control or techniques (i.e. non-chemical alternatives to pesticides). This Directive should be applied in each European country with the development of specific programs, such as the Ecophyto plan in France (Ecophyto, 2015). Consequently, this obligation has led to the development and introduction of new cropping systems built on agronomic, mechanical, physical, and biological principles which all contribute to the reduction of the reliance on pesticides (Barzman et al., 2015). The assessment of the

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impacts of innovative systems is a prerequisite to their effective implementation and adoption to avoid that an innovation becomes a new problem (Diederen et al., 2003; Lançon et al., 2007). Evaluating the sustainability of such cropping systems is a complex task which has focused, so far, on the economic, environmental or social impacts (Lechenet et al., 2014; Sadok et al., 2008; Sadok et al., 2009; Vasileiadis et al., 2013).

Humans are exposed to pesticides by a number of routes: during manufacture, mixing/loading, spraying, harvest, and by consumption of treated crops derived products (Damalas and Eleftherohorinos, 2011; Damalas and Koutroubas, 2016; Maroni et al., 1999). The estimation or measurement of human (i.e. operator, worker, resident and bystander) exposure to pesticides is mandatory for their registration (Regulation EC No 1107/2009, 2009). Regulators of EU member states evaluate the levels of exposure and the toxicological risks of each pesticide (i.e. active substance) and plant protection product (PPP, i.e. containing one or more active substances, in the form in which they are supplied to the user) for their intended uses to ensure they have no harmful effect on humans. Risk assessment is mainly based on laboratory studies using animal species, generally the rodent (Damalas and Eleftherohorinos, 2011; Regulation EC No 1107/2009, 2009). When available, medical data relating to clinical cases and poisoning incidents are also used. The assessment of human exposure also relies on predictive modelling approaches. Several models are used such as the EUROPOEM (EUR-Opean Predictive Operator Exposure Model) (van Hemmen, 2001), the UK approach (Chemical Regulation Directorate, 2008), or the German model (Martin et al., 2008). Recently, a European project has delivered BROWSE (Bystanders, Residents, Operators and WorkerS Exposure models for plant protection products) (Butler Ellis et al., 2017a; Butler Ellis et al., 2017b; Kennedy and Butler Ellis, 2017), an improved modelling framework for human exposure which integrates large European guidance and regulatory databases to refine the assessment of human exposure. BROWSE has been tested and led to more realistic exposure predictions than the existing models because of improvements in modelling: incorporation of many exposure routes, short term and long term exposures (Butler Ellis et al., 2017b). By using probability distributions to represent realistic variability in model parameters, instead of fixed high quantiles, the resulting exposure distributions output by the BROWSE software are considered to represent more realistic worst case scenarios with an appropriate level of conservatism (Butler Ellis et al., 2017b).

The exposure of humans to pesticides is usually assessed separately for each substance, even though humans can be exposed to a number of substances since several pesticides are commonly used to control various weeds, pests or diseases in the cropping systems. One study, that of Reganold et al. (2001), assessed the risks related to the overall use of pesticides in various apples perennial production systems using an environmental index which includes assessment of potential worker and consumer exposure to pesticides. They showed that organic systems ranked first in environmental sustainability, followed by integrated then conventional systems (the economic sustainability was also assessed and followed the same ranking). However, to the best of our knowledge, no risk assessment for human health of the overall pesticide use in cropping systems based on arable crops has been done. Thus, the objectives of this work were to assess and to compare, with the BROWSE model, (1) the human exposure to pesticides used in 3 conventional and 9 associated innovative cropping systems designed to reduce pesticide needs and (2) the corresponding risks for human health. As BROWSE considers only single pesticide usage per run, a method is proposed to represent the results obtained for all pesticides used in one system. This method enables to assess the overall pesticides risk for one system and then to compare various systems. The results will allow to identify the most efficient cropping systems to reduce the risks from pesticides for human health. The environmental (i.e. pesticides leaching), agronomic and technical (weed infestation, crop yield…), and economic performances of the systems will also be considered to determine whether the results obtained in this work are consistent with the recommendations based on the assessment of these other performances.

2. Material and methods

2.1. BROWSE model

BROWSE is a mechanistic model developed by the European project BROWSE (www.browseproject.eu) to predict human exposure from liquid and solid (including seed treatment) formulations of pesticides for the operators, workers, bystanders, and residents. From the amounts of pesticides humans are exposed to, BROWSE then estimates those that are likely to be absorbed through inhalation, dermal contact and ingestion. Finally, the model assesses the risk for human health due to the absorbed amounts of pesticides. This is explained in more details in Section 2.1.3.

The model uses a probabilistic approach allowing the determination of a distribution of exposures. This approach also ensures that the worst case exposures, obtained by consideration of the higher percentiles, are simulated in rare cases, and is meant to represent more realistic scenarios (Butler Ellis et al., 2017a; Kennedy and Butler Ellis, 2017). Conservative assumptions are built into the BROWSE model, for example when real data are not available to parameterise the model.

2.1.1. Definition of operator and residents groups

Operators are persons who are involved in activities relating to the application of a PPP: mixing/loading, application, emptying/cleaning the machinery after use, etc. They may be either professional or amateur users (EFSA, 2014). Workers are persons who, as part of their employment, enter an area that has previously been treated with a PPP or who handle a crop that has been treated with a PPP (EFSA, 2014). In the BROWSE model, there is no scenario of workers exposure for arable crops because these crops are harvested with machines, therefore workers are not considered in this work.

Contrary to the EFSA definitions (EFSA, 2014), for the purposes of the BROWSE model, residents and bystanders are considered as a single group of persons (named here as “residents”). This group could be located within or directly adjacent to the area where PPP application or treatment is in process or has recently been completed; their presence is quite incidental and unrelated to work involving PPP, but their position might lead them to be exposed, irrespective of whether they live there or just visit the site. BROWSE also makes the distinction between adults and children (Butler Ellis et al., 2017a).

2.1.2. Assessment of operator and residents exposure to pesticides

For operator, BROWSE considers three main routes of personal exposure: inhalation (via respiratory tract), dermal (via skin) and ingestion (via mouth). The dermal exposure is the most complex route of exposure and occurs through three potential pathways, i.e. deposition from the air, contacts of the hands and body with surfaces, direct transfer through splashes or dripping (from liquids) and impaction (from solids) (Damalas and Eleftherohorinos, 2011; Damalas and Koutroubas, 2016). The effects of work clothing and personal protective equipment (PPE) can be taken into account through coverage factors and pesticide migration factors through clothing and PPE.

For residents, BROWSE determines exposure to spray drift from boom sprayers during a spray application, as well as exposure to vapour and deposited spray drift following an application, assuming residents are immediately downwind of the application. For humans exposed during spray application, the routes of exposure are spray coming into contact with their skin (direct dermal exposure) and spray being inhaled (inhalation exposure). For humans exposed after spraying, the routes are breathing in vapour which is emitted from the crop after application (inhalation exposure) and drifting spray settling on the ground followed by skin contact with the contaminated ground