Science of the Total Environment 571 (2016) 819–825

Contents lists available at ScienceDirect

Science of the Total Environment

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

Field evaluation of two risk indicators for predicting likelihood of pesticide transport to surface water from two orchards

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HIGHLIGHTS

- Prediction of pesticide transport was validated against field monitoring data.
- Generally good agreement was found between the EPRIP and PIRI risk assessment.
- Field observations and EPRIP predicted concentrations generally agreed well.
- EPRIP and PIRI were found to be good predictors for a first tier risk assessment.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 2 June 2016
Received in revised form 6 July 2016
Accepted 7 July 2016
Available online 8 August 2016

Editor: D. Barcelo

Keywords:
PIRI
EPRIP
Insecticides
Fungicides
Field monitoring

ABSTRACT

Two pesticide risk indicators, Pesticide Impact Rating Index (PIRI) and Environmental Potential Risk Indicator for Pesticides (EPRIP), were used to determine the likelihood of off-site transport to surface water of pesticides used in a cherry (*Prunus avium* cultivars) and an apple (*Malus domestica* cultivars) orchard. The predictions of off-site transport of some of the pesticides were verified against actual pesticide concentrations in surface water continuously monitored over two years. To our knowledge, only one other study in the published literature has attempted this. Of the chemicals monitored there was good agreement between the predictions and the field measurements from the apple orchard, but less so for the cherry orchard. In both risk indicators the attenuation factor based on the width of the buffer strip over-estimated the effectiveness of the buffer strip. There was good agreement between the EPRIP and PIRI risk assessment except for ethephon which EPRIP rated a higher risk than PIRI and dithianon which EPRIP rated a lower risk than PIRI. A strong correlation was found between the field observations and the EPRIP predicted environmental concentrations for the majority of cases. This study showed that even simple risk indicators (e.g. PIRI and EPRIP) can be good predictors for a first tier risk assessment of pesticide transport to neighbouring water bodies.

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http://dx.doi.org/10.1016/j.scitotenv.2016.07.056
0048-9697/

1. Introduction

Off-site transport of pesticides into water bodies is a major concern in many countries. In the EU, for example, there has been an evolution in legislation, over several decades, in managing pesticides to decrease the polluting effects of agriculture and improve the quality of the environment (Finizio and Villa, 2002). A central theme in managing chemicals and minimising their environmental impact is risk assessment (van Leeuwen, 2007) which has been defined as 'the process of estimating the probability of a particular event occurring under a set of given circumstances' (Finizio and Villa, 2002).

Various risk assessment tools have been developed to assess the likelihood of chemicals with different properties and in different environments moving from the point of application to various environmental compartments. Risk indicators are easy to use tools that can aid in minimising off-site impacts of pesticides and can assist in decision making and policy formulations (Reus et al., 2002; Kookana et al., 2007). To be most effective, indicators need to predict the potential risk a hazard may pose which involves considering the rate and method of application of pesticides as well as environmental and site conditions (Reus et al., 2002; Kookana et al., 2005). One of the major challenges in developing a risk indicator is balancing the advantages of the user-friendly attributes of simpler systems, which may not provide enough information, with the data-richness of more complex systems that may provide more detailed output but may be prohibitively difficult to use. Levitan et al. (1995) reviewed the strengths and limitations of a range of assessment tools to evaluate environmental impacts of pesticides. They concluded that there is no one universal tool that can be recommended and the choice of risk indicator for use is determined by a range of factors including what question is being addressed, the level of complexity (or otherwise) required from the output, data availability for chemical application rates and frequency, ecotoxicological impacts (when ecotoxicology is considered), chemical fate in the specified compartment and environmental compartments to be considered (Levitan et al., 1995).

There have been a range of indicators developed in Europe, North America and Australia but there are two general types of pesticide risk indicators. Firstly there are those that use a ranking approach to generate potential risk scores, and then those that use some combination of ranks and predicted environmental concentrations (PECs). The indicators that use the ranking approach categorize data points on the pesticide's likelihood of moving to surface or groundwater and sometimes on the pesticide's toxicity to various target organisms. These indicators usually score pesticide properties first, which are then multiplied by the application rate. These indicators do not rely on the exposure-toxicity ratio (ETR) approach and do not make use of site specific data (Feola et al., 2011).

Other pesticide risk indicators rely on a more quantifiable PEC methodology to assess potential risk. In this latter approach the indicator uses environmental engineering equations in order to calculate the amount of pesticide that remains in different environmental compartments. The indicators that use a PEC methodology often also employ a ranking approach, either to categorize the pesticide's concentration or to categorize pesticide toxicity data (Greitens and Day, 2007). These risk indicators use site specific data and are more data demanding (Feola et al., 2011).

There have been several comparative evaluations of pesticide risk indicators (Maud et al., 2001; Reus et al., 2002; Stenrød et al., 2008; Whiteside et al., 2008; Bockstaller et al., 2009; Feola et al., 2011). Indicators differ with respect to the compartments considered (i.e. soil, surface water, groundwater and air) and effects taken into account and the results obtained can strongly depend on these factors (Reus et al., 2002). Maud et al. (2001) assessed five indicators and found they all did not consider multiple applications well, did not allow for synergistic effects of applying different pesticides together and none took application method or different formulation types into account.

In this study a comparison is made between two risk indicators: Pesticide Impact Rating Index (PIRI), which was developed at CSIRO in Australia (Kookana et al., 2005) and Environmental Potential Risk Indicator for Pesticides (EPRIP), which was developed for Italian agriculture (Trevisan et al., 2009). Feola et al. (2011) made a comparative evaluation of a set of seven risk indicators, for potential use in developing countries, including those relying on an ETR and those that do not. Both PIRI and EPRIP represent risk indicators using ETR. Feola et al. (2011) concluded ETR indicators, when user-friendly, showed a comparative advantage over non-ETR indicators.

We found only one paper in the published literature that had compared the results of the pesticide risk assessment with field collected data of pesticide concentrations in water. A recent study in South Africa compared the pesticide monitoring data results from a single runoff event from five sampling locations with the predicted relative exposure score of mobility determined using a GIS-based pesticide risk indicator (Dabrowski and Balderacchi, 2013). We utilised EPRIP and PIRI in estimating the potential risk of off-site movement of pesticides under specific conditions associated with horticulture (an apple, *Malus domestica* and a cherry, *Prunus avium* orchard) in the Mount Lofty Ranges, South Australia. The results from the risk assessment were then compared with actual pesticide concentrations detected in continuously monitored surface water samples collected at the edge of a field draining from the orchards over two growing seasons. This allowed us to make an assessment of the relative performance of two relevant risk indicators for predictions of pesticide transport in surface water against the field monitoring data. Such assessments are particularly scarce in literature.

2. Materials and methods

2.1. Background information about EPRIP

EPRIP was developed in Italy and calculates a PEC in the groundwater, surface water, soil and air compartments. It is discussed in detail elsewhere (Trevisan et al., 2009) but is briefly described below. EPRIP is based upon the ratio of PEC, which represents the estimated exposure at a local scale (field and surroundings) with short-term toxicity data. ETR values are transformed into risk points (RP) using a scale from 1 to 5 where the PEC value and corresponding RP are: <0.01 is RP 1, <0.1 is RP 2, <1.0 is RP 3, <10 is RP 4 and >10 is RP 5. The final EPRIP score is obtained by multiplying the RP values calculated for each compartment: surface water, groundwater, soil and air (Padovani et al., 2004). In this comparison only the surface water compartment was considered and the PEC data (mg/L) were determined for a single application as follows (Trevisan et al., 2009).

$$PEC_{runoff} = \frac{RATE \times (1-f_{int}) \times (1-f_{drift}) \times f_1 \times f_2 \times f_w}{P}$$

and for multiple applications (n) as

$$PEC_{runoff} = \frac{RATE \times \left[(1-\exp.^{-nki})/(1-\exp.^{-ki})\right] \times (1-f_{int}) \times (1-f_{drift}) \times f_1 \times f_2 \times f_w}{P}$$

These parameters and the data used for the sites reported in this manuscript are explained in Supplementary material, Table S1.

2.2. Background information about PIRI

PIRI risk indicator can be used to assess the relative risk of pesticides in terms of their potential impact on surface or groundwater quality and ecosystem health. Details of PIRI are given in Kookana et al. (2005) but a brief description is given below. PIRI is based on the threat (i.e. the pesticide load) to the water resource (L), and the fraction of pesticide transported through which the threat is released to the water resource (T). The components L and T are quantified using pesticide