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Simulating the fate of molinate in rice paddies using the RICEWQ model

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ABSTRACT

The contamination of drainage channels and creeks with pesticides used in the production of rice is of concern in south eastern Australia. Of major concern is the molinate that at times has been detected in over 25% of water samples from surface drains and creeks. The objective of this study was to evaluate the rice pesticide model RICEWQ version 1.7.2 for its applicability in simulating the fate of the pesticide molinate in paddy rice floodwater in south eastern Australia. The model was successfully calibrated using water depths and molinate concentrations obtained from a rice bay. By using the calibrated model, the effects of the different application methods and the rates of molinate on water quality were investigated.

The molinate, which was applied directly onto ponded water, led to higher maximum concentrations in the ponded water than for application onto a dry bay, which was subsequently filled. However, the concentrations in water declined more rapidly for the application onto a ponded bay than those for the application onto a dry bay. The simulation results suggest that water and chemical management has great effects on chemical concentration in the runoff water. Overall, the RICEWQ model accurately predicted the molinate concentrations in floodwater and this model can be used to develop best management practices in rice farming.

1. Introduction

There are 2.5 million ha of irrigated land in Australia, of which up to 120,000 ha are sown to rice annually and about 500,000 ha are in a rice growing rotation. The rice growing areas are within the Murray Darling basin on the Murrumbidgee and Murray Rivers in south western New South Wales and Victoria (Fig. 1).

Although the Australian rice industry is considered to be one of the lowest users of agrochemicals of all rice producers in the world, pesticide use remains significant (Bowmer et al., 1998). The management of pesticides in rice production can be a challenging task due to rapid runoff during high rainfall events, variable agronomic practices, and often close proximity of the rice fields to surface waters such as drains, rivers and wetlands. The contamination of drainage channels and creeks with pesticides used in rice production remains a concern in south eastern Australia (Bowmer et al., 1998). In Greece, a monitoring study was undertaken in the Axios river basin, the main rice cultivated area of Greece. It revealed that two rice herbicides, molinate and propanil, were frequently detected in soil water samples at concentrations exceeding 0.1 $\mu g\,L^{-1}$ (Papadopoulou-Mourkidou et al., 2004).

In order to reduce the environmental impact of molinate and other pesticides, a variety of measures are recommended to rice farmers so as to try to contain the chemicals on farms

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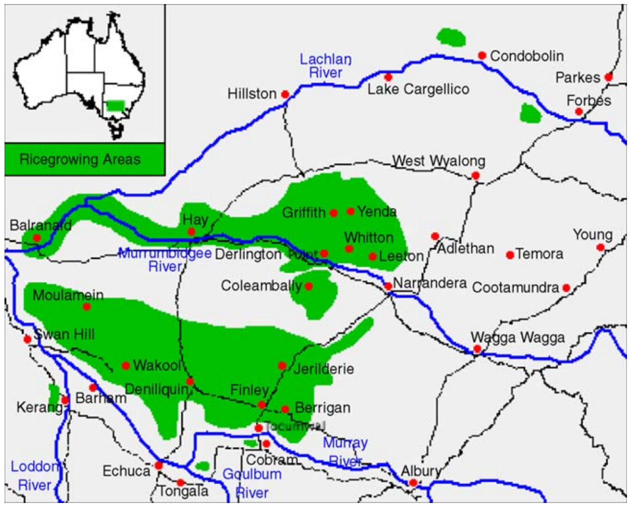

Fig. 1 – The rice growing regions of Australia.

(NSW Department of Primary Industries, 2005). The most important of these is the ''withholding period'', which is the period after the application of pesticide when water must not be released from the farm. The length of this withholding period for molinate is 21–28 days in the rice growing regions of Australia (NSW Department of Primary Industries, 2005; NSW Environment Protection Authority, 2004). The withholding period allows time for pesticide residues to dissipate to levels that are acceptable for environmental protection prior to being discharged from the farm. Despite these measures, the annual environmental reports of irrigation companies present the frequent detection of rice pesticides in surface drains. In some cases, molinate has been found in more than 25% of samples (Coleambally Irrigation Co-operative Ltd., 2002).

In order to gain further understanding of the fate of pesticides in rice paddocks, so that management practices can be devised and employed to minimise any harmful ecological effects, researchers have undertaken various studies to assess the dissipation rates of pesticides within rice fields (Deuel et al., 1978; Ross and Sava, 1986; Sonderquist et al., 1977; Papadopoulou-Mourkidou et al., 2004). One of the main pesticides concerned is molinate, which is used in rice fields during the period between October and November in order to control grass weeds. In bays nearest the irrigation supply in the Murrumbidgee Irrigation Area, molinate was found to be reduced by 99% within 19 days while residues remained for longer periods at the drainage end of the paddock (Bowmer et al., 1998). The large variability in biophysical and management conditions, however, makes it very difficult to produce definitive chemical management guidelines. Usually, the experimental resources required to monitor a broad range of conditions of chemicals are unavailable. Thus, the use of models to simulate varying biophysical and management conditions is useful in obtaining a broader spectrum of results that can be used to develop management guidelines.

Very few water quality models have been developed for rice production, and still fewer deal with pesticides. There are two detailed process-based models aimed at research: PADDY (Inao and Kitamura, 1999) and RICEMOD (FOCUS, 2003). A less detailed model developed for pesticide registration purposes in the USA is RICEWQ (Williams et al., 2004). The RICEWQ model was assessed by the Mediterranean-Rice group of the European Union. It was found to be the most suitable of those named above for the assessment of exposure risk to the surface waters neighbouring rice paddies (Karpouzas and Capri, 2004). RICEWQ has been validated in northern Italy where it adequately simulated pesticide dissipation processes (Capri and Miao, 2002; Miao et al., 2003a,b).

The main objective of this study was to evaluate the rice pesticide model RICEWQ version 1.7.2 for its applicability in simulating the fate of molinate (liquid formulation) in rice field floodwaters in south eastern Australia. Following successful calibration, the model was used to assess how different field water depths and different pesticide application methods could influence the concentrations of molinate in the runoff, and to provide management options to minimise off target contamination.

2. RICEWQ model

RICEWQ was developed to evaluate the fate and pathways of pesticides in rice paddies. It was developed by Waterborne Environmental Inc., in 1999 to address the main pesticide dissipation pathways while minimising input requirements. The model was developed specifically to simulate pesticide dissipation and runoff losses to receiving waters.

Water balance algorithms account for inflow to and outflow from paddy fields. Inflow includes irrigation and rainfall while outflow is comprised of runoff, evapotranspiration, and seepage. Irrigation is considered by either user-set ''fixed-volume'' mode or automatic mode. The automatic mode fills the bay to a set level when the water level in the bay drops to a critical level. The user sets the rate of filling at an available irrigation flow rate. Drainage outflow occurs when the water level in the paddy field reaches a critical level and it has an outflow rate given by the user. The model also allows for seepage from the bay.

The model applies a conservation of mass to simulate the fate of chemicals in the paddy. The RICEWQ tracks the fate of the chemical on the foliage, in the ponded water and in the bed sediment. The rate of the chemical application is attenuated by an application efficiency, which accounts for drift, rapid volatilisation and other immediate losses that prevent the chemical from entering the water column or being deposited on foliage. The pesticide mass is then either volatilised, degraded (hydrolysis, photolysis, metabolism), partitioned to sediment or lost by mass transfer through surface runoff.

Partitioning to sediment occurs by direct partitioning, diffusion and settling of chemicals, which are sorbed to the suspended sediment. These processes are represented simplistically and governed by rate terms input by the user. The model can track both parent and metabolite chemicals. For a detailed description of the model, see Williams et al. (2004).

3. Model calibration

The model was calibrated using molinate concentrations obtained from a rice paddy in the Murrumbidgee Irrigation