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Pesticide removal from cotton farm tailwater by a pilot-scale ponded wetland

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Abstract

A pilot-scale, ponded wetland consisting of an open pond and a vegetated pond in series was constructed on a cotton farm in northern New South Wales, Australia, and assessed for its potential to remove pesticides from irrigation tailwater. Ten incubation periods ranging from 7 to 13 days each were conducted over two cotton growing seasons to monitor removal of residues of four pesticides applied to the crop. Residue reductions ranging 22–53% and 32–90% were observed in the first and second seasons respectively. Average half-lives during this first season were calculated as 21.3 days for diuron, 25.4 days for fluometuron and 26.4 days for aldicarb over the entire wetland. During the second season of monitoring, pesticide half-lives were significantly reduced, with fluometuron exhibiting a half-life of 13.8 days, aldicarb 6.2 days and endosulfan 7.5 days in the open pond. Further significant reductions were observed in the vegetated pond and also following an algal bloom in the open pond, as a result of which aldicarb and endosulfan were no longer quantifiable. Partitioning onto sediment was found to be a considerable sink for the insecticide endosulfan. These results demonstrate that macrophytes and algae can reduce the persistence of pesticides in on-farm water and provide some data for modelling.

Keywords: Bioremediation; Organic pollutant; Half-life; Macrophyte; Sorption

1. Introduction

Despite a commitment to the rapid adoption of integrated pest management techniques, the cotton industry remains as one of the highest users of pesticides in Australian agriculture (Radcliffe, 2002). The herbicides diuron, fluometuron, prometryn and trifluralin are used widely for pre- and post-emergence control of weeds in fields of conventional cotton cultivars. The cyclodiene endosulfan, together with synthetic pyrethroid, organophosphate and carbamate insecticides, is applied routinely for the control of *Helicoverpa* spp., thrips and aphids.

Management of the off-farm movement of these chemicals, and potential contamination of surrounding

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ecosystems, has been addressed by the promotion of best management practices (Williams and Williams, 2000). These practices include increased care in the timing and methods of spray application to control aerial drift and the compulsory recycling of tailwater on-farm. In Australia, tailwater recycling is also necessary to gain the maximum economic benefit from a limited quantity of water allocated to farmers. Nevertheless, these practices result in the concentration of pesticides on farms, particularly in tailwater, and increase the risk of toxicity to livestock, farm workers and native plant and animal species (Sánchez-Bayo et al., 2002). Insects, amphibians and birds that are attracted by the large volumes of water on cotton farms (Sánchez-Bayo et al., 1999; Reid et al., 2003) are especially at risk. It is necessary to reduce the concentration and availability of these residues to minimise the risk for non-target species (Sánchez-Bayo et al., 2002).

Pesticide loss from aqueous systems has been well characterized and involves a combination of degradation and transport procedures. Degradation can include photolysis, chemical transformations and biological transformation (Roberts, 1998; Stangroom et al., 2000), of which microbial processes usually dominate (Vink and Van der Zee, 1997). Similarly, pesticide transport can be physicochemical or biological, but the parent compound remains unchanged; it is simply transferred from one matrix to another. Importantly, the rate of transport and breakdown of a particular pesticide depends heavily on its physicochemical properties (Stangroom et al., 2000; Crossan, 2002).

Constructed wetlands are gaining recognition as potential best management practices for the reduction of pesticide concentrations in agricultural runoff (Schulz, 2004). Generally, their success can be attributed to their diversity of function, as they improve the potential for the range of transport and degradation processes mentioned above. Most recent studies are concerned with mixed open water/vegetated constructed wetlands or fully vegetated constructed wetlands (Alvord and Kadlec, 1996; Schulz and Peall, 2001; Moore et al., 2002; Braskerud and Haarstad, 2003; Runes et al., 2003), with the aim of either quantifying pesticide removal or determining residence times needed in a particular wetland to remove a certain proportion of the chemical residue. In Australia, the scarcity of water means that any treatment of water must be rapid, with minimal loss from the system, which may occur by transpiration from aquatic macrophytes. Obstructions to water flow, the provision of refuge for weed and insect pests, and increased maintenance have also been discussed by growers as deterrents for operating vegetated wetlands on-farm.

In this study, an artificial wetland was established on a cotton farm in the Namoi River catchment near Narrabri, New South Wales, Australia. The objectives of the study were to (i) compare the rates of pesticide removal in an open (non-vegetated) and a vegetated pond, (ii) determine the fate of pesticides in the combined system, and (iii) assess the combined performance of an open and vegetated pond arranged in series in removing pesticides from tailwaters.

2. Methods

2.1. Description of the pilot-scale pond

The pilot-scale wetland system was established in September 2001, and basically consisted of a 1 m deep open pond of surface area 100 m^2 and a 0.5 m deep vegetated pond of surface area 200 m^2 in series (Fig. 1). Construction involved the excavation of the wetland ponds and installation of a depth indicator and flow meter to record water input and evaporation. An initial planting of the vegetated pond with native wetland species occurred on 1/11/01 and a second planting on 5/12/01, after which the wetland was filled with water from the nearby storage via the farm irrigation system. The species planted included knotweed (*Persicaria* spp.), water primrose (*Ludwigia peploides*), water milfoil (*Myriophyllum papillosum*), common rush (*Juncus usitatus*), clubrush (*Bolboschoenus medianus*) and cumbungi (*Typha domingensis*). At the end of the first season (March 2002), plant coverage

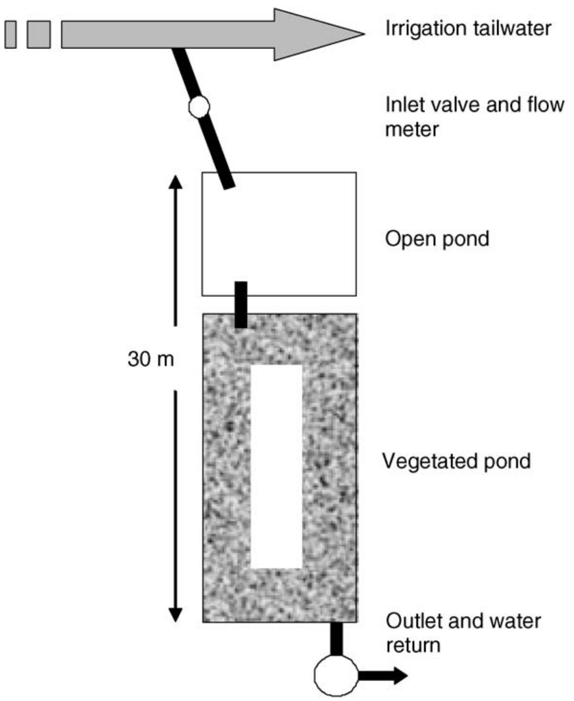

Fig. 1. Schematic diagram of the pilot-scale ponded wetland.