THE FATE AND TRANSPORT OF CHEMICALS ON FARM

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INTRODUCTION

In 1994, the Australian cotton farmer must use a wide range of costly chemicals to harvest a profitable crop. These chemicals vary significantly in their degree of hazard. Some chemicals (e.g. the organophosphates) directly threaten humans and other animals, because of their effect on nervous function. Others, such as the pyrethroids, are innocuous to humans, but toxic to fish. Still others, such as the esters of 2,4-dichlorophenoxyacetic acid (2,4-D) used on crops like wheat grown in rotation with cotton, are of concern because of their mobility in air and their possible effect on non-target crops such as grapevines or cotton. But currently, most attention is focussed on those that have potential environmental effects, such as endosulfan.

CHEMICALS UNDER SCRUTINY

Which chemicals are of most concern?

Although no guarantee can be given that any chemical used will continue to be regarded as completely safe, several can be singled out as of more acute concern. In recent years, the NSW Department of Water Resources Central and Northern Rivers Water Quality Program has published the results of analyses of river water throughout the cotton growing areas (Smalls, 1994; Preece *et al.*, 1993). Similar surveys are being conducted in Queensland. These surveys provide the best guide to the chemicals we need to be concerned about.

The chemical most consistently being measured in river water is endosulfan, each season the concentrations found substantially exceeding the recently introduced

prometryn and fluometuron also being detected in a few water samples. Other chemicals such as pyrethroids and organophosphates (e.g. profenofos) are not detected at the lower limits used to analyse the river water.

It is noteworthy that the contaminants being observed are either those of high rates of application (e.g. endosulfan) or are applied directly to drainage channels. It is unexplained that samples taken from the Gwydir river fail in a significantly higher percentage of water samples than do the Namoi and Macquarie river samples.

TRANSPORT MECHANISMS

What have we learnt about endosulfan movement on a cotton farm?
Several mechanisms for transport of chemicals on farms are now recognised.

Drift or volatilization at application

Despite the skill of aerial applicators, it is extremely difficult to spray pesticides without some off-target drift. Guidelines that have been provided for the use of pesticide applicators, as well as stricter legal requirements, have minimised the possibility of such drift from farms onto rivers or nearby human habitation. But the risk of drift remains (see Woods, 1994).

In addition to the direct drift of the spray droplets, there is the possibility of transport of an applied chemical as a gas or vapour . This can occur, for example, from the leaf surface into the atmosphere, particularly in the hours immediately after application, when the concentrations of the chemical are highest. Volatilization rate depends on the volatility of the particular chemical, the relative concentration at the source and in the gas phase and other physical factors such as wind speed and temperature. Endosulfan is much more volatile than the pyrethroids or organophosphates.

A glasshouse trial (Coleman, 1993) of the rate of dissipation of endosulfan applied to the leaves of cotton plants indicated that the bulk of the insecticide applied had disappeared within three days, about 10% remaining associated with the leaves as a metabolic product, endosulfan sulphate. Endosulfan sulphate is an effective insecticide but, unfortunately, toxic to fish. It can probably be assumed that more than half the endosulfan applied to the leaves of cotton plants will evaporate into the air and be diluted. This finding needs to be confirmed in the field, a study that is

being undertaken as part of the Joint Program of LWRRDC, CRDC and MDBC. No research on the fate of endosulfan as a gas in the atmosphere has been reported. While it can be assumed that it would be subject to oxidative attack catalysed by ultraviolet light and broken down, the rate of such degradation is unknown.

Leaching

Chemicals not bound firmly to soil components, such as clay surfaces or organic matter, can move downwards by mass transport in drainage water. Atrazine and diuron are subject to such transport but endosulfan is not. Studies in the laboratory and in the field (Kimber *et al.*, 1994) clearly indicate that endosulfan is firmly bound in the top few centimetres of soils on cotton farms. Leaching of endosulfan and transport in ground water below the water table does not occur. The pyrethroids, likewise, are unlikely to be leached, studies overseas and here (Wang and Kennedy, 1994) showing that these insecticides, which are of concern because they are also toxic to fish and crustaceans, bind firmly to soil.

Surface runoff from irrigation or storms

Endosulfan is clearly subject to surface transport in runoff from cotton fields.. Examination of tail water from both irrigation and storms reveals that significant amounts of endosulfan isomers and endosulfan sulphate are carried off field, at least during the spraying season (Tuite, 1993). The concentrations observed on farms are often greater than 1 ppb (1 µg/L) but it is likely that much of the chemical residues is bound to sedimentable soil particles. The 'half-life' of endosulfan residues measured in irrigation water run-off is about 1-2 weeks, with greater persistence of the residue fraction bound to sediments. Therefore, most of these residues in run-off water may have disappeared as a result of hydrolysis or volatilization within one month of the time of application.

Aeolian transport as dust

To the extent that pesticides are bound to soil, dust may be a vehicle for transport. The extent of this means of transport is unknown, but it is probably significant, at least locally.

The LWRRDC/CRDC/MDBC Joint Program is attempting to estimate the relative significance of different means of contamination (e.g. drift, vapour, dust, storm runoff).

BETTER MANAGEMENT

Are there any aspects which point to management opportunities to minimise pesticide transport off the farm?

The danger period for endosulfan transport is now clearly established as being the few weeks around and immediately after the time of application of endosulfan. At this time, surface runoff from cotton fields may contain more than 1000 times the ANZECC recommended levels of residues (0.01 ppb) regarded as consistent with the environmental health of rivers. Therefore, measures to prevent leakage of farm waters to the rivers at this time of the year are imperative. Runoff non-seasonally in winter, even though the cotton soils still contain significant concentrations of residues, is of much less concern and unlikely to seriously contaminate the river system.

Returning as much runoff as possible to storage dams (ring tanks) is highly desirable. The rate of decay of residue concentrations in the runoff water is sufficient that it could be feasible to 'quarantine' excess storm water at suitable locations (e.g. depressions and lagoons) for a period adequate to allow significant reduction in pesticide concentrations to be achieved. It is essential that such packages of contaminated water that may 'blow-out' be prevented from entering the river system too soon.

Because irrigation water has the potential to carry pesticides off-field in significant amounts, either dissolved in water or bound to soil particulates, spraying and irrigation should not be scheduled independently. Delaying irrigation even one day after spraying may halve the potential endosulfan residues in runoff, because of deeper binding in soil or volatilization to the atmosphere. Care to ensure that fields are not over-irrigated, keeping the runoff to a minimum volume, will also assist in minimising transport. Spraying directly onto fields with irrigation water in the furrows (see Cotton Yearbook, 1993) is clearly a foolish practice. The development of sediment traps, reducing the possibility of transport of bound pesticides to river systems would be beneficial. For the longer term, the retention of cotton stubble

residues, rather than burning, allowing decomposition in soil, would be expected to hasten the degradation of pesticides by stimulating microbial activity. However, this has not been experimentally tested.

ENVIRONMENTAL IMPACTS

Is the threat of endosulfan to the environment as severe as is publicised in the media and by environmentalists?

Endosulfan is of acute concern because it is so toxic to fish. However, there is some doubt whether endosulfan found in the river in summer is sufficient to kill fish often, particularly if it is bound to sediments. More likely, fish kills occur at points of direct contamination with a fresh formulation (e.g. drift, overspraying, malicious contamination) on farms close to the river. The cause of fish kills will become clearer when results are available next year from studies in progress on the ecotoxicology of endosulfan bound to sediments, being conducted as part of the Joint Program by the NSW EPA.

There remain questions related to other environmental impacts of this chemical. A study by Peterson and Batley (1991) showed that some species were barely affected at levels several hundred times those routinely see in the river system, so that many species appear to tolerate endosulfan quite well. Endosulfan does not accumulate from year to year in soil (Kimber *et al.*, 1994) or in the fatty tissues of animal stock, because of its significant rate of conversion to non-toxic products (e.g. endosulfan diol). Compared to other organochlorines such as DDT and dieldrin, it is a much safer or 'softer' chemical.

However, a decision about whether the current levels of contamination are acceptable to the Australian community seems already to have been taken in the very low concentrations recommended by ANZECC. These clearly present a strong challenge to the cotton industry, as the major user of endosulfan. Given the likelihood that the dependence on chemicals such as endosulfan can be reduced progressively over the next few years, as a result of development of pest-resistant cotton (e.g. Bt toxins), or the encouragement of beneficial predators of pests, one would predict a progressive reduction in the extent of river contamination. Goals

could be set to reduce levels of contamination. In the case of endosulfan, the technology is already available, or is about to be developed, to facilitate this process or to allow it to be monitored accurately (e.g. immunoassays, Skerritt, 1994). The nature of the cotton industry is such that a high degree of voluntary compliance with recommendations can be expected. A precipitate decision to restrict or to ban the use of endosulfan might be strongly counterproductive. No alternative to endosulfan as satisfactory for application in insect resistance strategies is available. Therefore, farmers might need to apply excessive amounts of any replacements selected, with unpredictable environmental consequences. On the other hand, a carefully managed strategy of reduced use of endosulfan coupled to use of the alternative strategies discussed elsewhere in this conference could be the vehicle of achieving improved practices that would be a object lesson to all in the cotton industry as well as agriculture at large.

GUIDELINES FOR FARMERS

There is a strong case for agricultural industries to act responsibly, erring on the side of caution in matters regarding the use of farm chemicals. No cotton farmer will rationally use any more chemicals than are absolutely necessary, if only because of cost. Equally, cotton farmers will have no wish to expose families and friends or the environment at large to the effects of chemicals, however slight the risks. Thus, guidelines that will minimise these risks should be welcomed by the farming community. While there is insufficient space here to provide a comprehensive set of guidelines, the following brief suggestions may be considered, in addition to those already available from earlier projects such as the Environmental Audit conducted on behalf of the cotton industry (Gibb Environmental Sciences & Arbor International, 1991).

1. The environmental fate of all chemicals used in cotton growing should be known, using field data obtained under Australian conditions. This includes knowledge of the persistence or rate of degradation of each chemical in cotton farming systems (i.e. its 'half-life') and a clear understanding of the possible mechanisms of transport from sites of application, as well as knowledge of its ecotoxicology. Before new chemicals are introduced, the same knowledge should be available. This understanding and

knowledge should be available to provide guidance to farmers and consultants, allowing them to plan farming operations to minimise impacts on the environment.

2. The industry should develop procedures to maximise the containment of all chemicals applied on the farms. Doing so will minimise the exposure of the environment at large to the chemical. The use of irrigation systems in which all waters can be retained and recycled on farms, or at least held in temporary holding areas to allow dissipation of chemicals, should be adopted.

3. Natural processes of bioremediation should be fostered as part of the farming operation and new measures to allow accelerated bioremediation developed and applied as soon as possible. The means to monitor and ensure that chemicals are eventually degraded to harmless products such as those given by 2,4-D on degradation (i.e. carbon dioxide, water and chloride) should be available. Information about such processes needs to be made available to farmers, consultants and other workers in the cotton industry, so that these measures may be applied.

These suggested guidelines are directly related to the three current projects included in the research program on Environmental Protection (fate and transport, containment and bioremediation) included in the activities of the Cooperative Research Centre for Sustainable Cotton Production, for which the author is research leader. It is anticipated that the means to comply with the suggested guidelines will be obtained, during the next few years.

Perhaps a valuable concept or vision to develop is that of farmlands as productive parklands, fostering biodiversity of both flora and fauna, with farmers acting as 'custodians of the landscape' at the same time as they make a good living. This can only be achieved gradually by careful planning to achieve sustainable cotton production systems. However, such farm parklands would not only produce fibre and food but also social amenities of touristic value, an improvement in the national resource base and considerable aesthetic appeal, for which farmers could reasonably expect some economic return. Some farmers already think on these lines, but there is a need to more rigorously establish the conditions under which such a vision may be achieved.

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