

6.1 Case study, catchment water quality and cotton: northern NSW

Warwick Mawhinney
DIPNR, Tamworth

Key points

- Since monitoring of pesticide residues in surface water began in 1991, the most commonly detected insecticide has been endosulfan.
- Restrictions on endosulfan use, and further emphasis on the cotton industry's integrated pest management system (IPM), best management practice strategies and the introduction of genetically modified and insect tolerant cotton varieties, have resulted in a reduction in the detection of endosulfan residues.
- Atrazine is the most commonly detected herbicide and since 1992 the most commonly detected pesticide in groundwater is atrazine. Atrazine is not used for cotton production and is more commonly used in dryland grain crops.
- Irrigators should monitor the quality of the water that they pump into storages to ensure they are not salinising their own land.
- Some degree of contamination of surface and groundwater will always occur in agricultural areas. Our common aim should be to minimise the impact.

Australia is a dry continent, and we are all aware of the value of good quality water. It protects public health, supports economic production and maintains a healthy river ecosystem. Water quality is largely determined by land use, geology, climate, riparian vegetation and stream flow.

Alteration of the landscape since European settlement has resulted in marked changes in catchment conditions. Since then, land use has had an increasing impact on water quality. Agricultural activities such as land clearing, broadscale cultivation, irrigation and grazing can increase levels of turbidity, salinity, nutrients and pesticides in our waterways.

Water quality within cotton-growing regions of northern NSW is being monitored by DIPNR. These results show the levels of insecticides (in particular endosulfan) are decreasing, while herbicides continue to be detected at numerous sites throughout the region.

A review of water quality in rivers of North-West NSW

The Central and North West Regions Water Quality Program (CNWRWQP) was jointly funded by

the then Department of Land and Water Conservation and the water users of the Macintyre, Gwydir, Namoi and Macquarie valleys. The project commenced in the early 1990s and focused on the impacts of agriculture on water quality. Nutrients, salinity, turbidity and up to 34 agricultural chemicals were monitored, at a number of sites, over a ten-year period.

Pesticides

The detection of pesticides (including insecticides, herbicides and defoliants) in surface water is of great concern to water managers and the community as a whole, as the effects of long-term, low dose exposure of humans and the environment to pesticides are largely unknown.

Spray drift, vapour transport and run-off are the main pathways for pesticide transport into river systems (Mawhinney 1998, Raupach et al. 2001). Spray drift and vapour both contribute low level but almost continuous inputs to the riverine ecosystem during the peak spraying season. Spray drift occurs when pesticide droplets, while still in the air, move away from the target area into neighbouring environs. The likelihood of pesticide

drift is influenced by weather conditions, the method of application, equipment used and crop structure. Therefore it is important that these factors be considered before spraying.

Run-off tends to provide occasional high concentrations of pesticide contamination. Pesticides in run-off can be dissolved in the water, bound within sediments or adsorbed onto suspended particles. One way to reduce the amount of pesticides in our river systems is to minimise run-off from agricultural land and

associated sheet, rill, gully and stream bank erosion. Research by Rosewell (1988) has shown that the amount of run-off from even a short fallow is increased five times, compared to pasture, while soil erosion is magnified by a factor of eight to 20 times. Poor soil structure increases run-off and erosion. The pulverising effects of cultivation and the loss of organic matter are the two factors that most disrupt the soil structure in agricultural systems.

The pesticides that were regularly detected through the CNWRWQP in

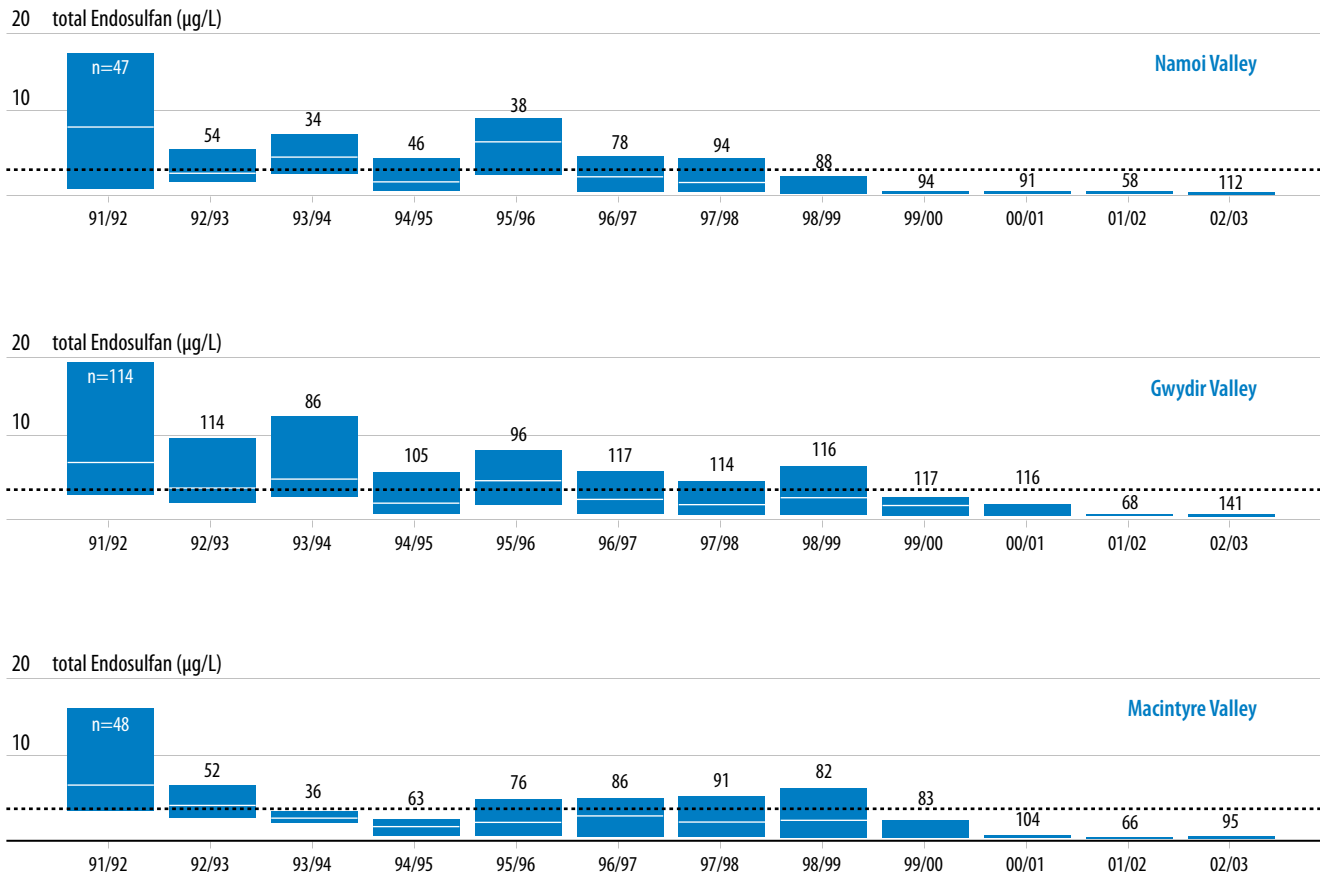
the Namoi, Gwydir and Macintyre valleys, and the number of detections in each sampling year, are given in Table 6.1.1. The number of samples includes all sampling sites across each valley, not just those located in the main cotton-growing areas.

Table 6.1.1: Number and percentage of detections of common pesticides for all samples collected across all sites in the Namoi, Gwydir and Macintyre valleys from 1991/92 through to 2002/03

	Endosulfan	Atrazine	Diuron	Fluometuron	Metolachlor	Prometryn	Simazine	No. samples
1991/92	174 (59%)	136 (46%)	60 (20%)	16 (5.4%)	0	41 (14%)	ns	296
1992/93	194 (65%)	113 (38%)	28 (9.4%)	17 (5.7%)	0	32 (11%)	ns	299
1993/94	137 (65%)	71 (34%)	28 (13%)	19 (9.0%)	14 (6.7%)	15 (7.1%)	ns	210
1994/95	135 (48%)	106 (38%)	27 (9.6%)	10 (3.6%)	2 (0.7%)	12 (4.3%)	ns	281
1995/96	169 (58%)	178 (61%)	14 (4.8%)	2 (0.7%)	25 (8.6%)	23 (7.9%)	0	291
1996/97	207 (52%)	138 (35%)	24 (6.0%)	32 (8.1%)	21 (5.3%)	39 (9.9%)	0	395
1997/98	196 (49%)	86 (21%)	40 (10%)	70 (17%)	37 (9.2%)	48 (12%)	3 (0.7%)	404
1998/99	182 (46%)	131 (33%)	79 (20%)	73 (18%)	53 (13%)	31 (7.8%)	8 (2%)	400
1999/00	126 (31%)	177 (43%)	75 (18%)	66 (16%)	58 (14%)	35 (8.5%)	2 (0.5%)	413
2000/01	76 (17%)	184 (42%)	57 (13%)	86 (20%)	59 (14%)	25 (5.7%)	18 (4.1%)	438
2001/02	14 (4.8%)	81 (28%)	28 (9.7%)	21 (7.2%)	15 (5.2%)	17 (5.9%)	18 (6.2%)	290
2002/03	4 (1.1%)	69 (20%)	27 (7.8%)	18 (5.2%)	9 (2.3%)	10 (2.9%)	3 (0.8%)	348

ns = not sampled

Figure 6.1.1. Box plots of total endosulfan results by river basin from 1991/92 to 2001/02



The broken line represents the Australian and New Zealand water quality guideline trigger value (ANZECC and ARMCANZ 2000) for 99% ecosystem protection (0.03 µg/L). Each box represents the middle 50% of the data collected for each year. The middle line in each box represents the median (or 50th percentile) value, which is the most useful when assessing water quality data.

The most commonly detected insecticide in north-west NSW from 1991 to 2002 was endosulfan. From 1991 to 1999, about 50% of samples contained residues of endosulfan (Table 6.1.1). Endosulfan concentrations in the Namoi, Gwydir and Macintyre valleys from 1991 to 2002 are given in Figure 6.1.2. A similar contamination pattern is visible in all three valleys. The highest level of contamination by endosulfan occurred in the 1991/1992 growing season. This coincides with the rapid expansion of the cotton industry and

a relatively low awareness of best practice methods compared to today's standards. Levels dropped in 1994 and 1995 in response to the drought, as the area sown to cotton was greatly reduced, so that the amount of endosulfan applied was significantly less than previous years.

In 1998/1999 endosulfan residues were detected in cattle. The result was the introduction of greater restrictions on endosulfan use, and further emphasis on the cotton industry's best management strategy. Figure 6.1.1 shows how these

two factors resulted in a dramatic reduction in endosulfan in the three valleys during 2000/2001 and 2001/2002. For the first time in ten years endosulfan residues were not detected in the Namoi River during the 2001/2002 spray season. The endosulfan monitoring results are also compared to the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC and ARMCANZ 2000) trigger value for 99% ecosystem protection (0.03µg/L) as shown by the dashed line in Figure 6.1.1. The 99% ecosystem protection

level means that 99% of species are expected to be protected if the concentration remains below the trigger value. Only in recent years have endosulfan concentrations fallen below the guideline level across all three valleys.

Other insecticides detected through the CNWRWQP were chlorpyrifos, profenofos, dimethoate, propargite and parathion. The detection of these insecticides was more sporadic than that of endosulfan, due to different chemical properties and generally lower usage rates. However Muschal and Warne (in press) have demonstrated that occasional high concentrations of chlorpyrifos and profenofos can have a deleterious impact on the aquatic environment.

The broken line represents the Australian and New Zealand water quality guideline trigger value (ANZECC and ARMCANZ 2000) for 99% ecosystem protection (0.03 µg/L). Each box represents the middle 50% of the data collected for each year. The middle line in each box represents the median (or 50th percentile) value, which is the most useful when assessing water quality data.

The most commonly detected herbicide through the CNWRWQP was atrazine (this includes the active ingredient and the two major breakdown products hydroxy-atrazine and desethyl-atrazine). From 1991 to 1999, as many as 61% of samples contained atrazine or one of its breakdown products. Table 6.1.1 shows that, in most cases, the percentage of samples containing pesticide residues dropped in 2001/2002. Other herbicides detected were diuron, fluometuron, metolachlor, prometryn and simazine. Metolachlor was most commonly detected in the Namoi Valley, while

diuron, fluometuron and prometryn were more commonly detected in the Gwydir Valley. Little is known regarding the long-term impacts of herbicides on river ecosystems.

Salinity

Most landholders are well acquainted with the term salinity. Salinity is the presence of dissolved salts in soil and water and is a problem common to many parts of Australia. It may be caused by the presence of salt in underlying soil or bedrock, salt deposited due to past marine inundation of an area, or salt carried over the land surface from the ocean. Changes in land use can make this salinity problem worse. The replacement of native trees and grasses with annual crops and pastures, overgrazing and long fallows has increased the amount of water entering the watertable. During times of low rainfall, as the watertable falls, salts are concentrated in the soil. These salts can then be flushed into streams by run-off. Some streams may also be fed directly by saline groundwater. The most saline creeks and rivers in north-west NSW are located in the mid to upper parts of the catchment. Prolonged irrigation with saline water can exacerbate soil salinisation by providing salts in addition to those already present in the soil profile. Irrigators should monitor the quality of the water that they pump into storages to ensure they are not salinising their own land.

The most common measurement of salinity is electrical conductivity (EC), measured in microsiemens per centimetre (µS/cm). Electricity is conducted more easily (and therefore EC rises) as the concentration of dissolved salt increases. Figure

6.1.2 shows the median electrical conductivity at three sites, Namoi River at Bugilbone, Mehi River at Bronte and Barwon River at Mungindi, which are all located at the lower end of the major cotton-growing areas in each valley. In most years the Namoi Valley had the highest median electrical conductivity readings, while the Barwon River at Mungindi was consistently lower. The fluctuations from year to year are largely due to changes in flows due to rainfall, run-off and releases from storages.

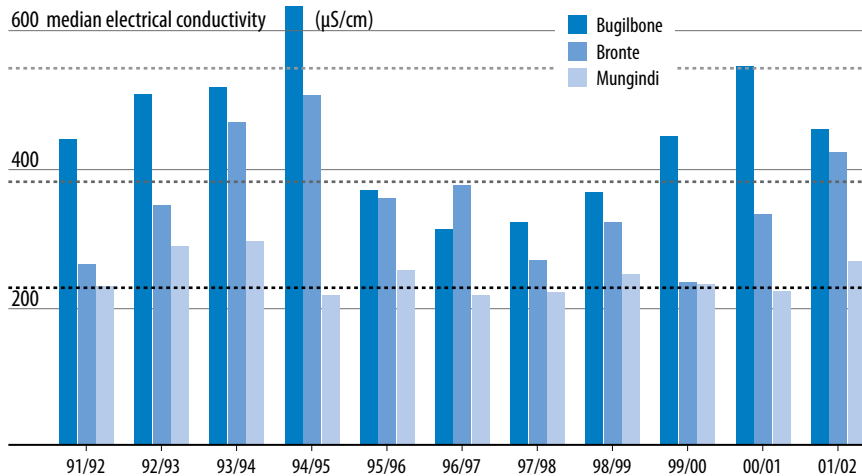
The Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ 2000) classify water with an electrical conductivity of less than 650 µS/cm as a very low salinity rating and being suitable for irrigating sensitive crops. These guidelines also provide trigger values, which are alert levels above which action should be taken to assess if there is potential impact on aquatic ecosystems. The generic trigger value for electrical conductivity in western NSW lowland rivers is 300 µS/cm.

In addition to this trigger value, the Catchment Management Board Blueprints have set specific end-of-system salinity targets for the Namoi (550 µS/cm), Gwydir (390 µS/cm) and Border Rivers (230 µS/cm) catchments. The blueprints specify that these targets for each valley should not be exceeded more than 50% of the time. Since 1991, the Namoi River at Bugilbone reached or exceeded the valley target four times and the Barwon River almost always reached or exceeded its target over the ten-year sampling period (Figure 6.1.2). Increased end-of-system salinity levels appear to be linked with low flows, as concentrations rose during the drought period of 1992 to 1995 and again in 2000 to 2002.



Figure 6.1.2. Median electrical conductivity ($\mu\text{S}/\text{cm}$) for three sites (Namoi River at Bugilbone, Mehi River at Bronte and Barwon River at Mungindi) located downstream of major cotton-growing areas and other land uses in each valley from 1991/92 through to 2001/02

Lines indicate Catchment Management Board salinity targets for the Namoi (----), Gwydir (----) and Border Rivers (----).



The phosphorus and nitrogen levels in the Namoi, Gwydir and Macintyre valleys are not limiting to algal growth. This means there are ample nutrients available in the water for the formation of algal blooms when conditions are favourable. Every year we see algal blooms in the large storages in the region, usually over summer, and blooms in the Barwon-Darling have been well documented.

Nutrients

Sources of nutrient contamination include sewage treatment works, farm effluent, run-off from agricultural land, septic tanks, industrial effluent and urban storm water run-off. Phosphorus and nitrogen are the main nutrients of concern. Similar to pesticides, phosphorus and nitrogen can be dissolved in water, bound within sediments or adsorbed onto suspended particulate matter (for example, soil or organic matter). In north-west NSW, run-off from agricultural land is the main source of nutrients, with the movement of nutrients attached to suspended material the main transport mechanism.

High concentrations of nutrients are important factors in the formation of blue-green algal blooms. Nutrient levels do not actually trigger an algal bloom, but determine how large the bloom becomes. Other factors such as water temperature, turbidity and water turbulence are also important. Blue-green algae can contain toxins which may cause severe dermatitis and conjunctivitis in people coming into contact with the algae through swimming or showering, and may cause stomach cramps, nausea, fever and headaches if consumed. Blue-green algae can also produce toxins that attack the liver and other internal organs and can act as neuromuscular blocking agents, leading to respiratory arrest (Chorus and Bartram 1999). Stock deaths in north-west NSW have been attributed to water contaminated by toxic blue-green algae.

Off-farm impacts

Bowmer et al. (1995) and Napier et al. (1998) reviewed NSW and Queensland fish kill registers and media reports between the mid 1970s and 1995. Bowmer et al. (1995) concluded that *'despite all the difficulties in assessing the evidence, it is still clear that cotton pesticides are causing the majority of those fish kills that have been reported, and that endosulfan is the pesticide most often implicated'*. Napier et al. (1998) concurred with this conclusion. An assessment of risk posed by pesticides to aquatic biota in rivers by Muschal and Warne (in press) determined that atrazine, diuron, fluometuron, metolachlor and prometryn posed either a low or moderate hazard to aquatic organisms. Their results also indicated that chlorpyrifos, endosulfan and profenofos posed a genuine risk to aquatic biota from acute exposures (brief exposure at high concentrations), and endosulfan also posed a risk from chronic exposures (continued exposure over a long period).

As endosulfan concentrations in the rivers have fallen in recent years, so too have the number of reported fish kills. Agricultural chemicals are not the only cause of fish kills: they can also be caused by the dramatic decline in water quality due to the 'first flush' effect. Many floods commence with an event characterised by high levels of sediment and nutrients at the very beginning of water levels starting to rise. This is often due to the sudden disturbance of the stream bed, and the purging of nutrients and poorly oxygenated water from standing pools. It is the toxic effect of these high concentrations of pollutants and low dissolved oxygen that appears to

be the cause of recent fish kills, rather than chemical contamination. An example occurred in the Barwon River at Banarway Crossing in December 2002. In this instance a 'fresh' in the Moonie River flushed turbid, nutrient-rich and oxygen-depleted water into the Barwon River, resulting in more than a thousand dead fish.

Groundwater quality

Long fallowing, low water-use cropping and clearing of native vegetation have contributed to shallow, saline watertables, by increasing deep drainage of water through the soil profile. Shallow saline groundwaters can contribute to soil salinisation and can also leak downwards, contaminating deeper aquifers used for irrigation. This process is likely where excessive extraction causes long-term drawdown of groundwater levels. Consequently, groundwater quality and quantity issues are closely related, with hydraulic linkages meaning that maintaining good quality groundwater involves total groundwater management (Timms 1998).

Pesticides have been detected in groundwater in many different locations (Jiwan and Gates 1994a, 1994b, 1995; Timms 1997), with detections having a patchy and localised distribution. Since 1992 the most commonly detected chemical has been atrazine. Heavy black clays and proximity to cropping appears to be the major determinant for groundwater contamination by pesticides (Timms 1997). Observations in the field suggest that groundwater contamination by atrazine generally occurs in close proximity to sorghum crops.

Atrazine has high water solubility, suggesting the predominance of diffuse contamination pathways through the soil profile. Isolated cases of low level contamination by diuron, fluometuron, metolachlor, simazine and trifluralin have also been found.

In addition, the contamination of bores by residues from abandoned chemical drums has been highlighted as a point source for chemical contamination. Chemicals with low water solubility and low mobility (for example, trifluralin) have been detected in such bores. Chemicals can leak directly into aquifers via backflow down the bore if drums are abandoned near poorly constructed bore heads, or during mixing and rinsing. The absence or poor maintenance of cement-lined mixing bays next to bores means that excess mixing waters drain into depressions close to or around the bore head and percolate directly to groundwater. This problem of point-source contamination is easily prevented with better farm management practices.

Once a pollutant enters an aquifer, depending on local groundwater conditions, it may either degrade, absorb onto aquifer materials or be transported laterally with groundwater flow. Unfortunately it is difficult to determine which mechanism is predominantly responsible for decreasing pesticide concentrations over time. Once an aquifer is contaminated either by chemicals or salinity, remediation of the aquifer is very difficult and very expensive. Prevention of aquifer contamination is strongly recommended.

Options to reduce the transport of pollutants off-farm

Improved surface and groundwater quality is possible, and the options to achieve it are not new. Most of the surface water quality problems are related to run-off. This is where improvements to land management and farming practices in a catchment area will achieve the best results. If run-off can be reduced, filtered by vegetation or stored on-farm, and then used before it can leak through the soil profile into shallow groundwater, many of the water quality problems could be solved.

The issue of groundwater contamination is complicated, mainly due to the lack of knowledge on agricultural chemical pathways through the soil profile. However, identified point sources of pollution, such as chemicals backflowing down bores and the over-extraction of deeper aquifers, can be addressed.

It must be remembered that some degree of contamination of surface and groundwater will always occur in agricultural areas. Our aim should be to minimise the impact. Management options that will achieve this goal include:

Adoption of best land, soil and vegetation management practices:

- maintaining at least 70% ground cover to reduce run-off and erosion;

- management of run-off through tailwater retention and prevention of tailwater releases (for example, 'blow outs');
- good soil management to improve organic matter content and soil structure; and
- good agronomic practices (for example, spray at optimum time, use certified seed).

Riparian vegetation management:

- exclude livestock from vegetated buffer strips along all creeks, rivers and major drainage lines (except for 'crash grazing', that is, a short period of intense grazing to keep rank growth in check, but not long enough for the animals to cause any damage along the riverside)
- install constructed watering points in stable areas to minimise streambank erosion and nutrient inputs by livestock
- maintain vegetated buffer strips down slopes of cropped paddocks and vegetated waterways to intercept and filter run-off water and minimise spray drift
- on-going maintenance of bore heads to prevent groundwater contamination by pesticides
- use of best management practices for chemical application to minimise the transport of chemical off-farm.

Water quality guidelines

For more information on National Water Quality Guidelines, see the following internet sites.

Guidelines for fresh and marine water quality www.erin.gov.au/water/quality/nwqms

Australian Drinking water guidelines www.health.gov.au/nhmrc/publications

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