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Designing irrigation systems to improve water quality

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One of the biggest challenges faced by irrigated agriculture in Australia is to resolve the conflict over water allocations. The use of water must become more efficient and sustainable to prevent the depletion of environmental flows and recharge.

According to the Australian Bureau of Statistics, there has been a 35 per cent increase in water use for cotton in Australia since 1993–94 without a significant increase in the available water. The recycling and reuse of water is therefore becoming more important to maximise economic and environmental benefits.

The majority of cotton farms in Australia use furrow irrigation. In this process, relatively clean river or underground water picks up plant material, sediments, microorganisms and chemicals present on the soil surface. The runoff is returned to large storage dams without treatment — so water quality may decline on cotton farms throughout the season.

Cotton storage dams and irrigation channels have become surrogate habitats for native flora and fauna. Unfortunately, the quality of water in these structures can sometimes be detrimental rather than beneficial to them.

Reduced water quality could also present a greater risk of illness to livestock and farm workers, increase the potential spread of cotton diseases around the farm, and importantly, put limitations on the possible end use for that water. Cleaner water means more flexibility in decision-making and associated economic benefits.

The aim of this article is to identify the factors that comprise water quality, examine how they affect cotton production and suggest simple methods of designing irrigation and storage systems to enhance water quality.

The Australian Cotton CRC with National Heritage Trust funding has been conducting feasibility trials to determine local benefits of constructed wetlands, so improved water quality can be achieved economically on cotton farms as part of the farming operation.

Pilot-scale sub-surface filtration system at Auscott Narrabri.

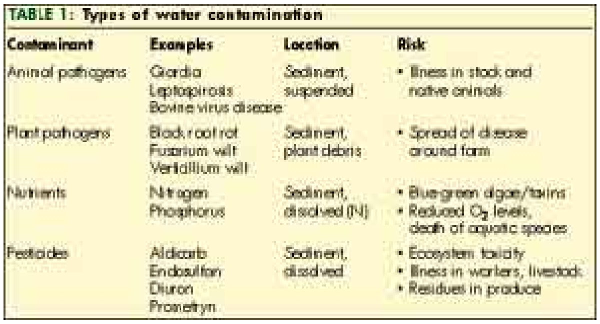


TABLE 1: Types of water contamination

Contaminant	Examples	Location	Risk
Animal pathogens	Giardia Leptospirosis Bovine virus disease	Sediment, suspended	• Illness in stock and native animals
Plant pathogens	Black root rot Fusarium wilt Verticillium wilt	Sediment, plant debris	• Spread of disease around farm
Nutrients	Nitrogen Phosphorus	Sediment, dissolved (N)	• Blue-green algae/toxins • Reduced O_2 levels, death of aquatic species
Pesticides	Aldicarb Endosulfan Diuron Prometryn	Sediment, dissolved	• Ecosystem toxicity • Illness in workers, livestock • Residues in produce

A trial ponded wetland on ‘Mollee’ in the Namoi valley.

What are the indicators of water quality?

Indicators of water quality can be physical, biological, microbiological or chemical. Farmers will often have an idea of the quality of water on their property simply by observing any changes in physical characteristics of the water, such as colour, odour and turbidity, and the biology (type and livelihood) of any organisms using that water.

For example, the development of ‘scum’ on the water surface coupled with a rotting odour and the presence of dead fish gives a clear indication that the water is not fit for drinking!

Unfortunately, not all cases are this clear cut — the degree of the water quality and cause of any fouling is usually more difficult to determine. In these instances, microbiological and/or chemical testing is necessary. In fact, the biological status of water — which is what we are most concerned with — is nearly always dependent on these other two factors.

But the contaminants of concern depend on the desired end-use for the water. For example, although certain water may not be fit for human consumption, it may still be suitable for use in the irrigation of cotton. So we need to address potential contaminants individually.

Animal pathogens

Contamination of farm water by animal pathogens can be important on cotton farms as they are typically run in conjunction with cattle production. If stock are watered from troughs or other above ground structures, contamination is rare. But if their water source is surface water, such as in dams or channels, pathogens may be present from faecal contamination by livestock or native animals.

Plant pathogens

Cotton is susceptible to a number of plant pathogens. The most significant are the soil-borne fungi (Table 1) that infect cotton plant roots, often at different stages and under different conditions. One of the main mechanisms by which they move around within farms is via irrigation tailwater, either in sediment or on plant trash.

Guidelines from the Australian Cotton CRC suggest that run-off from affected fields should be kept out of distribution systems to prevent infection of clean fields, but treatment by sub-surface flow wetlands is a possible solution.

Nutrients

In an undisturbed state, Australian soils and waters are generally low in nutrients. Native flora and fauna have adapted accordingly, so an excess of nutrients can unbalance the natural ecosystem. One outcome of nutrient enrichment is eutrophication by algae, with the dominance of a few fast-reacting species and a reduction in biodiversity.

Cyanobacteria (blue-green algae) in particular are quick to proliferate. Some of these photosynthetic bacteria produce secondary substances that are toxic to animals. Another

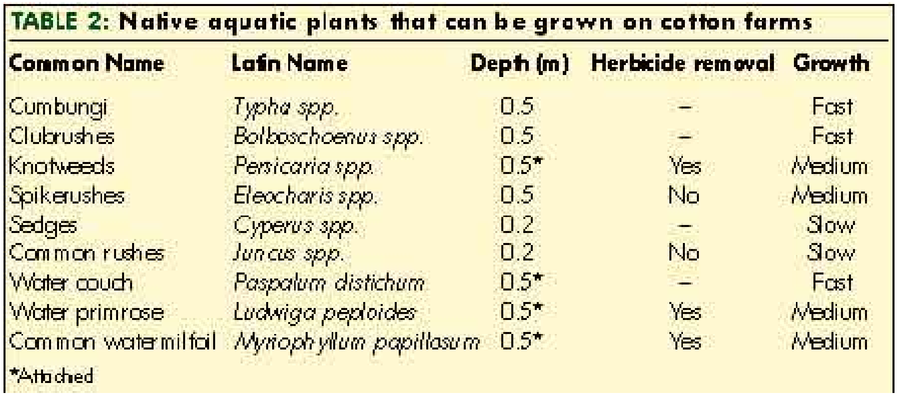
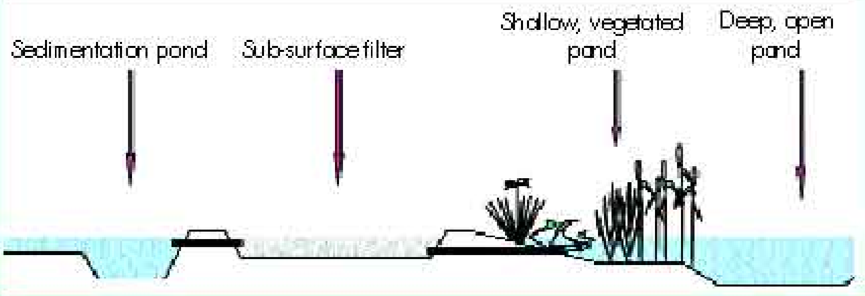


TABLE 2: Native aquatic plants that can be grown on cotton farms

Common Name	Latin Name	Depth (m)	Herbicide removal	Growth
Cumbungi	*Typha spp.*	0.5	–	Fast
Clubrushes	*Bolboschoenus spp.*	0.5	–	Fast
Knotweeds	*Persicaria spp.*	0.5*	Yes	Medium
Spikerushes	*Eleocharis spp.*	0.5	No	Medium
Sedges	*Cyperus spp.*	0.2	–	Slow
Common rushes	*Juncus spp.*	0.2	No	Slow
Water couch	*Paspalum distichum*	0.5*	–	Fast
Water primrose	*Ludwiga peploides*	0.5*	Yes	Medium
Common watermilfoil	*Myriophyllum papillosum*	0.5*	Yes	Medium

*Attached

FIGURE 1: An example recirculation and storage system to enhance water quality



outcome of eutrophication is a reduction in dissolved oxygen levels due to the increased respiration by aquatic microorganisms. This can cause the suffocation and death of fish and other aquatic organisms. So it is desirable to remove excess nutrients from farm runoff water.

Pesticide residues

It is unusual to find tailwater totally free of pesticide residues. This does not mean that all tailwater is acutely toxic to animals and plants using that water, but it can increase the risk of toxicity — both acute and chronic.

Furthermore, even though residues may not be toxic, they can be detrimental to the marketability of a number of other products that may be grown in conjunction with cotton, such as cattle (recall endosulfan or Helix) or grain. It is in the best interests of growers not only to decrease the usage of pesticides, but also to remove any residues remaining in tailwater following irrigation.

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Flow-through filters

Filtration is an effective method of removing pollutants. Water can be filtered by pushing it through porous material, either passively under gravity or actively by pumping. For the low-level pollution and high volumes of water found on cotton farms, gravity-driven flow is usually sufficient and a lot more cost effective.

Depending on the level of clean up required, a number of different materials can be used. Coarse particles, including cotton trash and larger sediments, can be removed simply by allowing a body of water to slowly flow through a stand of aquatic plants.

This reduces the velocity of the water, allowing the larger particles to sediment out under gravity and floating trash to beach itself on shore. Aquatic plants may also bind some chemical contaminants, but the extent of this depends on the water speed and plant density.

To remove finer particulates, a method known as sub-surface flow can be used. This involves filtering water through a bed of porous material such as gravel, wood chips, or sand.

Generally the finer the composition of the porous material, the finer the sediment removed. Sub-surface flow also increases the contact of the water with the solid surface, and reduces pollution by physical interactions — that is, binding or sorption. Because fine sediments also hold the highest percentage of nutrient and pesticide residues on a weight basis, sub-surface flow also helps remove these chemical contaminants.

The length of flow-through filter required depends heavily on the volume of water and load of contaminants that needs treatment, and the level of treatment that is desired. A pilot-scale system on Auscott, Narrabri, has been established to develop these guidelines

Shallow, vegetated ponds

Aquatic plants can assist in the clean up of water in a number of ways. But apart from some floating and submerged species, most require shallow (maximum 0.5–1.0 metre deep) water for growth. Examples of species that have been successfully established in pilot-scale wetlands in cotton tailwater are shown in Table 2.

Lab trials have identified some of these species that can directly reduce herbicide concentrations by direct uptake. Residues removed in this way are usually either irreversibly bound or metabolised into non-toxic products.

All of the above species, and indeed other suitable plants, also enhance pollutant removal via a number of non-specific mechanisms.

First, because they require nutrients for growth, aquatic plants can remove excess nitrogen and phosphorus from tailwater. The rate at which this occurs depends on the species.

Second, they contribute decaying organic matter to the water and sediments, which binds nutrients, pesticides, detergents and oils. Dissolved organic matter, such as humic acid, can also speed up the breakdown of some pesticides in a process known as photo-sensitisation. Plant material also acts as a food source for beneficial microorganisms that speed up pesticide breakdown and enhance nutrient cycling.

Third, many aquatic plants transport oxygen into otherwise anaerobic sediments. Again, this increases the rate of pesticide breakdown and nutrient cycling.

A pilot-scale ponded wetland has been established on ‘Mollee’, a cotton farm near Narrabri, to determine whether aquatic plants can enhance pesticide residue degradation under field conditions. Results over two seasons indicate that pesticide removal is 20 per cent higher than non-vegetated ponds under normal conditions, but open water can be as effective in some circumstances. Overall, the Cotton CRC study has shown that over 50 per cent of pesticides in runoff can be removed by such constructed wetlands in 10 days.

Deep, open ponds

Depth is a good way to regulate water velocity and naturally assists in sedimentation of heavy particles. Although it is possible to grow floating plants in deep water, it is often better to leave deep ponds free of vegetation to allow penetration of light.

Pesticide breakdown is increased in open water relative to shaded water by exposure to UV light on cloudless days, in a process known as photolysis. Sunlight also promotes algal growth that can assist in pesticide degradation.

But under most circumstances, open water bodies should follow on from an initial treatment to reduce nutrient concentrations — such as filtering or vegetated ponds — to prevent the growth of unwanted blue-green algae (Figure 1). This pretreatment also decreases turbidity and thus allows better light penetration.

A further benefit of having sections of open water is the destruction of animal pathogens. Most animal pathogens are relatively fastidious, requiring conditions similar to those found in animal guts for survival and proliferation. So in aquatic environments, pathogens will usually die out over time without special treatment, due to unfavourable climatic conditions, exposure to sunlight (ultraviolet light) and competition and predation by other indigenous microorganisms. Treatment wetlands for this purpose should be designed with a retention time of greater than a week and at least 50 per cent open water.

Aeration

As previously mentioned, the majority of pesticides degrade faster to non-toxic products under aerobic condition. Similarly, the cycling of some nutrients requires oxygen. So processes that increase the oxygen content of water can help remove pollutants

Oxygen is best introduced into water physically. The easiest method of achieving this is by increasing water movement that incorporates air, rather than the more expensive method of bubbling aeration like in a fish tank.

One example would be to design return channels that incorporate baffles (a fancy word for underwater hills). Another inexpensive method of providing aeration is to position existing structures such as pumps or other moving machinery near deep water to improve mixing.

Wetting and drying

A number of the processes above involve the removal of pollutants on sediments or filters. Because these usually remain underwater for long periods, pollutant breakdown can be slow. Again, aeration is a solution. Good aeration can be achieved by completely drying out storage dams and channels.

Excavation

The accumulation of sediment can fill water storage areas and channels rapidly, even over one season of irrigation. It is important to monitor these areas to identify when such sedimentation is limiting not only to water storage and movement, but also the capacity for pollutant removal.

As commonly occurs on most cotton farms during the non-growing (winter) season, channels and storages should be excavated to alleviate sedimentation. This sediment is comprised of fine, usually nutrient-rich clays and organic material and is usually relatively fertile.

If possible it would be beneficial to return and incorporate any excavated sediment back onto fields. In doing so, any remaining pollutants are again aerated and dispersed to reduce levels further.

Potential benefits?

- Greater end-uses for recycled tailwater. Depending on the degree of treatment, tailwater may be re-used for purposes other than the irrigation of cotton. This may include aquaculture or the irrigation of other crops that are susceptible to cotton herbicides found in untreated tailwater.

- Reduced spread of water-borne cotton pathogens.

- A decrease in the chance of illness in livestock and native fauna resulting from ingestion of water contaminated with pathogenic bacteria and viruses.

- An immediate benefit to the farm ecosystem and the surrounding environment. In particular, native fauna that passively use recycled water, such as water birds and amphibians, are at a lower risk of suffering illness from pesticide residues, animal pathogens or algal toxins.

Clean water on farms also promotes an increase in biodiversity, thus fostering those benefits discussed earlier. Furthermore, in the event that tailwater does escape off farm, the risk of toxicity to the surrounding environment will be lowered.

For more about constructed wetlands on cotton farms, including assistance with planning, contact the authors on phone: 02 9351 2112 or Email: mros3133@mail.usyd.edu.au; a.crossan@agec.usyd.edu.au

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