Herbicide Trials for the control of submerged aquatic weeds

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Abstract

Submerged aquatic plants pose problems in Australian and New Zealand waterways for navigation, flood management, bank erosion, recreation and aesthetics. Among problematic species are: Lagarosiphon (*Lagarosiphon major* (Ridley) Moss), Egeria (*Egeria densa* Planch.), Hornwort (*Ceratophyllum demersum* L.) and Elodea (*Elodea canadensis* Michx.). These species prefer clear water, where they form dense stands. The problem in controlling these plants relates to their mode of spread; the smallest viable vegetative fragment can re-establish a population. Left uncontained, these aquatic weeds are likely to fully colonize all available habitats, within a short period of time.

Recent advances in application technology have allowed the safe use of aquatic herbicides in control programs. A new technique for applying the aquatic herbicide- Diquat for the control of submerged aquatics has been developed in New Zealand. This method involves the use of guar gum, and formulating a Diquat gel form (Hydrogel®), which can then be applied to water. Hydrogel provides a greater degree of control, and allows the targeting of specific areas while significantly reducing offsite herbicide drift.

Treatment trials of the formula “Hydrogel”, were undertaken at a number of sites in New Zealand and NSW, against a range of submerged aquatic weeds. Results indicate that control can be achieved at significantly less cost than control by mechanical and other means. Water quality monitoring results show negligible herbicide residues downstream of the treatment sites. Future trials will be undertaken to assess the long-term control options for aquatic weeds using Hydrogel and other aquatic herbicides. Larger-scale trials will be undertaken to assess the environmental fate of herbicides in water and the wider aquatic ecosystem. The ability to use herbicide for the control of submerged aquatic weeds will significantly improve the cost-effectiveness and environmental effects of river control works, channel clearing and dam maintenance in the future.

INTRODUCTION

A number of submerged exotic aquatic weed species have colonized Australia and New Zealand's waterways, assisted mainly by human activities. The main species are: Lagarosiphon (*Lagarosiphon major* (Ridley) Moss); Egeria (*Egeria densa* Planch.); Hornwort (Ceratophyllum demersum L.); and Elodea (*Elodea canadensis* Michx.). In addition, other submerged aquatics- Hydrilla (*Hydrilla verticillata* (L. f.) Royle), Moss, Pond weed (*Potamogeton crispus* L.) and Cabomba (*Cabomba caroliniana* Gray) also present significant threats.

There have been considerable efforts in both countries to keep waterways weed-free. Over the past 45 years many techniques have been tried for aquatic weed eradication, or to manage the adverse effects of these weeds on aesthetic, recreational and economic values of waterways.

The objectives of this paper are to: (a) Review how aquatic weeds have been managed in Australian and New Zealand's waterways, and (b) Discuss the potential of a relatively new technique of applying aquatic herbicides for aquatic weed control.

REVIEW OF AQUATIC WEED MANAGEMENT OPTIONS

We carried out an extensive review of aquatic plant management in both countries gathering information on methods, up-to-date costing and logistics issues. Information was collected from aquatic weed control contractors, scientists and field managers, as well as from published literature. Table 1 provides a summary of non-chemical methods commonly used, costs, applicability and disadvantages.

AQUATIC HERBICIDES

Aquatic weeds can be controlled effectively and cheaply by aquatic registered herbicides, when compared to mechanical methods, but the time and method of herbicide application varies with the type of weed and the habitat in which they are to be controlled. The herbicides most widely used in Australia and New Zealand in underwater treatments are Diquat and Endothal. Both have sound environmental profiles and concentrations required for control of aquatic weeds, they are relatively safe for humans, fish and other aquatic fauna at. They are not persistent chemicals. However, when applied correctly, they have a high degree of phytotoxicity to kill aquatic weeds fast and rapidly degrade in the water after the action on weeds. Technology should be available for their application in static or flowing water systems.

Diquat dibromide (Reglone®) has been used for over 40 years in New Zealand and Australia for the control of submerged species. Diquat does little harm to non-nuisance native species, such as charophytes, and native potamogetons and milfoils (Wells and Clayton 2005).

Table 1. Non-chemical Aquatic plant management methods commonly used in Australia and New Zealand

Method	Application	Main disadvantages	Cost/ha ($ NZ)
Hand Weeding	Useful for controlling small (<1 m^2), localised, sporadic and patchy infestations	Labour intensive; Not an option for larger infestations	$ 7000-10,000
Mechanical digger	Artificial canals, shallow canals, lake shoreline areas	Loss of benthic fauna and fish; high turbidity, anoxia; widen/deepen drains; spreading weeds	$ 1000-3500 ($ 2500-5000)
Roto-tiller	Can uproot weeds in water depths between 1.5-4 m; Deeper tilling provides longer control (1-2 years vs. 6 months).	Lakebed obstacles prevent effective use. Regrowth can be increased; roto-tilling is like a plough, creating more habitat for rooted aquatic weeds.	$ 2000 (shallow) $ 5000 (deeper, up to 5 cm)
Mechanical weed cutter/harvester	Can target a specified area and cut to a nominated depth; Costs depend on density of weeds and distance to disposal site.	Quick re-growth could occur; requires repeated cutting (2-3 times in a growing season); potential to spread weeds, as fragments inevitably escape.	$ 2,000 - 4,000
Suction dredging	Use of suction pump to uproot aquatic weeds and collection in a mesh bag; Can give effective control up to 3 years.	Re-establishment can be as short as two months for hornwort. It is also ineffective in hard-bottomed or rocky substrates.	$ 15000- 20000
Nutrient control	Nutrient reduction through riparian buffers or by nutrient removal by flocculation using products like Phoslock®	Costly; depending on the amount of phosphate to be removed and the nature of the lakebed substrate.	$ 6000 – 10000 (Phoslock)
Shading and bottom lining	Dyes (Aqua shade®, Nigrosine) to suppress light and plant growth; Polyethylene, PVC, or fibreglass covers, as bottom linings.	Use is limited to smaller water bodies; adverse long-term impacts are largely unknown, although unlikely to be high.	$ 5000 - 15000
Water level manipulation	Lake draw-down is widely practiced in lakes with controlled outlets; often in hydro-power generating systems.	Re-growth can be rapid when lake refills; also, high cost (through lost hydro-generation potential) and adverse impacts (erosion, slumping).	Varies
Chinese Grass Carp *Ctynopharyngodon idella* (Valenc.)	Widely used in NZ, but not in Australia; feeds non-selectively on a range of submerged or floating soft plant tissues. Unlikely to breed in NZ waterways.	Unknown impact on some native aquatics; limited success in larger lakes, because of fish losses through escape and predation. In Lake Hood, ≈ 30 fish/ha provided required weed control.	$ 750 ($25 per fish)

New Zealand's National Institute for Water and Atmospheric Research Ltd (NIWA) recently conducted a risk assessment of Diquat use in Lake Karapiro. The report pointed out that Reglone® (20% a.i. Diquat dibromide) is diluted 100,000 times by water to attain the concentration required for control of waterweeds, which is equivalent to 1 mg L^{-1} of Diquat dibromide (Clayton and Severne 2006). This is equal to only 1 drop of Reglone® product in 10 litres of water. The concentration of Diquat in water rapidly declines after application as a result of dispersion, plant uptake and adsorption to organic and inorganic (negatively charged) particles. When applied to weed beds in an open waterbody, the concentration of Diquat often falls below detection limits within 1 hour of being applied. No evidence exists for toxic accumulations of Diquat residues in bottom sediments following repeated usage. The review concluded that although the Diquat concentrate is a toxic substance, at the rates required for control of nuisance submerged weeds, it is so diluted that it is less toxic than other common household products such as chlorine as used in swimming pools.

Endothal (Aquathol® and Aquathol Super K®) has recently been registered for use in New Zealand, but significant restrictions yet remain on its use. Endothal has been found to be superior to Diquat for controlling *Hydrilla* (Hofstra and Clayton 2001, Hofstra *et al* 2001).

The mode of delivery of herbicides is very important to effectively control submerged aquatic weeds. Various gel adjuvants have been mixed with Diquat, such as alginate gum (Torpedo®), guar gum (Aquagel®) and methocel (hydroxypropyl methylcellulose, marketed as Depth Charge®). All formulations are applied at 60 - 80 L ha^{-1}. When applied as a steady stream, the mixtures sink and attach onto submerged weeds and Diquat is released into surrounding water, causing desiccation of aquatic weeds. Aquathol Super K contains an additive, which performs a similar function to the Diquat adjuvants. The most widely used gel adjuvant is Aquagel, marketed as Hydrogel® in Australia.

Hydrogel is made of guar gum, a non-toxic polysaccharide starch, which can be mixed on site to any desired viscosity (LINZ 2003). It is superior to alginate gum, as it retains a consistent viscosity at any temperature. If viscosity varies with temperature, the delivery equipment requires recalibration throughout the day. The relatively heavy nature of the gel carrier prevents Diquat from being dispersed, as it sinks in the water column and lands on target foliage.

Diquat directly acts on the plants with its toxic action, but does not leave a residue in the sediments; nor is it bio-accumulated in animal tissue (LINZ 2005). The starchy polymer is non-toxic to the environment and is dispersed in water. Hydrogel can be applied into water from a knapsack, gun and hose, boat-mounted boom or helicopter-mounted boom. Aerial spray drift is reduced to near zero; and water dispersal and drift is also significantly reduced.

Several case studies are presented from New Zealand and Australia, which demonstrate the possibilities of controlling submerged aquatics with Hydrogel.

Case Study 1- Hornwort in Moutere Stream, Nelson, South Island, NZ

Hornwort was not previously known in New Zealand's South Island, and the aim was therefore to eradicate it from the infested location- Moutere Stream, in Nelson. Aquagel treatments were first made in March 2002 (LINZ 2003), applied in strips (60 cm wide), over about 800 m of the stream; 195 L of Aquagel covered 0.7 ha. The applications contained the label recommended rate 6.0 kg Diquat Dibromide per hectare.

The cost of this treatment was NZ $ 4500. After 6 weeks, all Hornwort had collapsed, and was no longer noticeable in the stream. Spot treatments were conducted 12 months later. Monitoring of the stream in November 2003 and February 2004 found no Hornwort in the treated area.

Case Study 2- Lagarosiphon in Lake Benmore, South Island, NZ

Lagarosiphon invaded Lake Benmore in South Island in March 2002 and large patches were found over a 100 ha area of lakebed from 1-4 m depth. While eradication was not considered possible in this case, containment was a priority to prevent downstream spread throughout the catchment (LINZ 2003).

Aquagel, containing the label recommended rate of Diquat per ha, was applied from a helicopter over the infested 100 ha site in March 2003. Helicopter spraying is cost-effective and accurate treatments can be made to specific areas of a large lake in a very short time. The cost of treating the Lake was NZ $ 1425/ha. Monitoring found that the spraying was highly effective. While immediate eradication of Lagarosiphon from the Lake is unlikely, the rate of spread has slowed, largely as a result of Aquagel treatments. Monitoring, including samples of Eel taken before and after treatment, indicated that the use of Diquat to suppress Lagarosiphon biomass in the Lake did not result in any residual Diquat entering the food chain (LINZ 2005).

Case Study 3- Hornwort and Cabomba in Botany Wetlands, Sydney

Botany Wetlands (Longitude 151 10'-151 15'; Latitude 33 55'-33 58'), in Sydney, are a series of freshwater ponds. After a sustained program of removing European Carp (*Cyprinus carpio*), during 1996 to 2002, a dense Hornwort infestation covered the largest of the ponds- Pond 5 (17 ha). Carp, as bottom-feeders, kept submerged aquatic plant growth in check, but a large reduction in adult Carp during the first 5-6 years of the program coincided with the explosion of Hornwort infestation, which covered 95% of the pond.

A single Hydrogel treatment, over a 600 m^2 infested area (. 4 L at a cost of Aus $ 250) was effective in achieving clear water within 4 weeks. In other areas of Botany Wetlands, trials are in progress, testing Hydrogel effectiveness on Cabomba. Initial results are that multiple treatments have reduced Cabomba in trial plots by about 50%. Optimisation of a treatment regime is envisaged in the near future.

Case Study 4- Egeria in Sutherland Shire, NSW

Hydrogel application was trialled to eradicate a 500 m^2 Egeria infestation in Sutherland Shire, NSW, Australia. One treatment of 3 L Hydrogel completely eradicated the infestation within 2 months (Figure 1). The cost of this treatment was Aus $ 275.

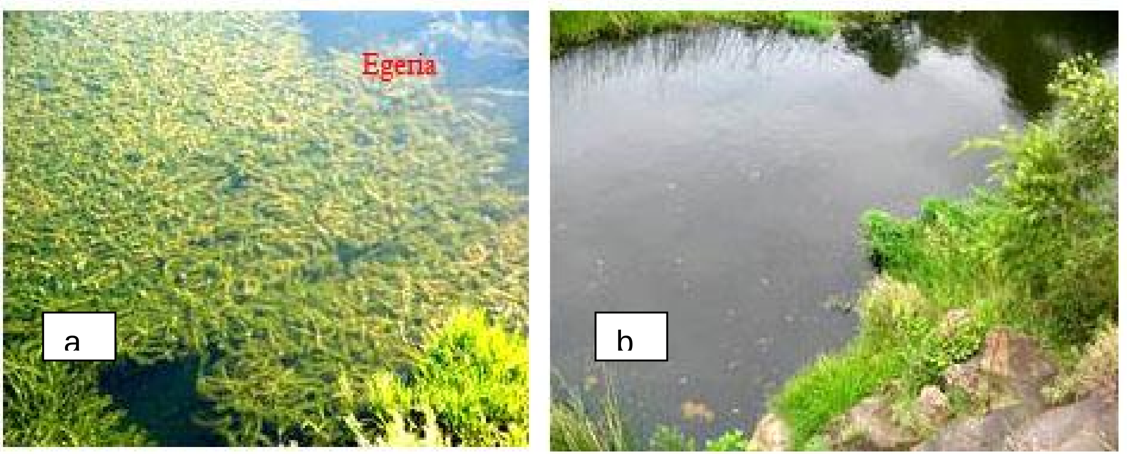

Figure 1. (a) Egeria infestation in Sutherland Shire (b) Control with Hydrogel.

Case Study 5- Egeria in Georges River, Liverpool, NSW

Similar Hydrogel application trails were conducted at an Egeria infested reach of the Georges River, Sydney. The area treated in January 2007 was 2500 m^2. One treatment of 15 L Hydrogel completely eradicated the infestation within 2 months (Figure 2). The cost of this treatment was Aus $ 600.

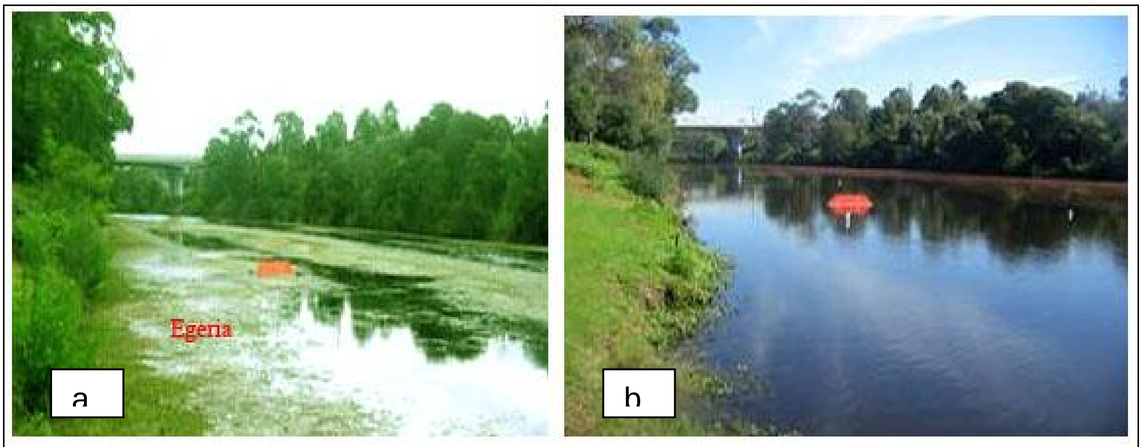

Figure 2. (a) Egeria infestation in a section of Georges River, Sydney, NSW; (b) Control achieved by Hydrogel 2 months later.

Discussion

In our view, there is a significant body of evidence from New Zealand and increasing evidence from Australia that the effectiveness of aquatic herbicides can be improved, to suppress extensive areas of critical aquatic weeds infestations quickly at a relatively low cost. Use of smart delivery systems, such as Hydrogel, allows for this, particularly to accurately deliver the required dosage over a treatment area, without wasting chemicals.

Hydrogel treatments make the control significantly more cost-effective than control by other methods. Additional advantages are that Hydrogel treatments do not generate unsightly piles of Lagarosiphon, Egeria or Hornwort on shorelines and applications require a much smaller suitable weather window, because of the speed of application and action, and the result is often long lasting. The differential response in submerged plants (i.e. reduced effectiveness on Cabomba) could be related to less retention of Hydrogel on the fan-like Cabomba leaves. However, we believe that with optimization of formulations and possibly with the use of different aquatic herbicides, Cabomba control should be achievable.

The use of Diquat/gel (Hydrogel) for aquatic weed control is now widespread throughout New Zealand's waterways. Its social acceptance is rapidly improving, as evidenced by most territorial authorities allowing its use as a permitted activity (i.e. no Council discharge permit required). In Australia, experiments are in progress, still under a trial permit, and success is spectacular in some cases.

Although herbicides are the most cost-effective method of aquatic weed control, there is an understandable general community aversion for using chemicals in water. This aversion can often prevent the use of herbicides over large areas. In this situation, Hydrogel is useful because it allows less number of treatments and specific targeting, reducing herbicide loads and offsite drift.

The development of new techniques for aquatic weed control needs to continue, despite the relatively small market in this field. The potential environmental impacts and monetary costs of many of the other control methods means that more attention is needed for aquatic herbicides and smart delivery systems to achieve superior results.

TAKE HOME MESSAGES

A number of submerged aquatic weeds have colonized Australian and New Zealand waterways, assisted mainly by human activities. They out-compete native vegetation and cause various problems in waterways.

Management of submerged aquatic weeds could be achieved by a number of methods, and it is often best to integrate the least environmentally damaging methods, suitable to a particular situation.

Most non-chemical methods are not cost effective, and are of limited value in controlling these species. Mechanical methods, such as dredging, may also cause unacceptable environmental harm.

In contrast, aquatic herbicides offer more promise for cost-effective control and the registered chemicals have proven environmental safety.

The new technique for applying the aquatic herbicide Diquat for the control of submerged aquatics- formulating a Diquat gel-Hydrogel® shows considerable promise for application in water bodies without undue environmental impacts.

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