EXPANDING THE LIST OF AQUATIC HERBICIDES FOR USE IN AUSTRALIA – THE CONUNDRUM OF DO WE STOP, WELCOME OR REMAIN NEUTRAL ON ITS EXPANSION?

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ABSTRACT

The nation's capacity to effectively manage aquatic weeds is hindered by a lack of available tools, in particular registered herbicides. Herbicides are acknowledged as the primary control tool and a vital component of most integrated aquatic weed management strategies. In Australia, weed managers have been limited to the use of 17 registered or approved (under minor use permit) herbicides. Thirteen herbicides are available for aquatic areas, three for irrigation and drainage channels and one for estuaries and inlets. Many of these herbicides have been used since the 1950s. The advent of aquatic plant resistance to existing herbicides heightens the need for additional herbicides for aquatic weeds management.

This project engaged relevant experts from state and federal agencies involved in aquatic weed management, to identify suitable herbicides for use in aquatic systems and review data limiting herbicide approval in Australia. Twelve active ingredients were identified with new formulations and chemistry that pose reduced risk to aquatic organisms and potentially improve the control of many floating, submerged and semi-terrestrial aquatic weeds within Australia. In addition, use of an expanded range of herbicides could delay aquatic plants developing herbicide resistance, which is exacerbated when using only a few herbicides.

Keywords: aquatic herbicides, risk assessment

INTRODUCTION

Aquatic weeds, particularly non-native invasive species, are serious threats to ecosystems in Australia. The proliferation and continued spread of these weeds restricts water movement in irrigation canals, reduces biodiversity, threatens endangered flora and fauna, increases sedimentation rates in reservoirs, degrades water quality, increases mosquito breeding habitat and causes major economic losses to agriculture, recreation, fisheries, water suppliers and property values. In addition, species such as cabomba (*Cabomba caroliniana*) can form dense populations that pose safety problems for swimmers and boaters. Current annual expenditure in Australia is estimated at over $7.3 million for mechanical and chemical control (NAWMG 2008). Despite this expenditure for the containment of aquatic weeds, submerged aquatic species such as cabomba, semi-aquatic species such as alligator weed (*Alternanthera philoxeroides*) and floating species such as water hyacinth (*Eichhornia crassipes*) continue to spread.

Alternative non-chemical control options for aquatic weeds that are operationally or economically viable are limited, placing greater emphasis on the use of herbicides. Aquatic weed managers must minimise adverse environmental impacts when using chemicals to control weeds. In Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) regulate chemical use, with State/Territory governments also regulating chemical use in their jurisdictions. Currently, 17 herbicides (2,4-D, acrolein, amitrole, carfentrazone, calcium dodecylbenzene sulfonate (CDBSA), copper, dichlobenil, diquat, diuron, endothal, fluazifop-P as butyl, glyphosate, guar gum, haloxyfop, orange oil and simazine) are registered or approved under a minor use permit for aquatic use in Australia (Infopest 2012).

Weed resistance to herbicides is an emerging issue in aquatic plant management. The intensive use of fluridone in the mid 1980s for whole-lake and large scale management of Hydrilla (*Hydrilla verticillata*) in the USA resulted in fluridone-resistant Hydrilla, requiring up to six-fold higher application rates for control (Michel *et al.* 2004). Cross-resistance in aquatic plants has also been shown with diquat-resistant duckweed (*Lemna minor*) being cross-resistant to paraquat. Such resistance strengthens the need for additional management tools and new herbicides for weed management.

This project sought new and safer aquatic herbicides, methods for improved efficacy and efficiency of existing herbicides, strategies to reduce adverse effects of herbicides on aquatic ecosystems and, in the long-term, an integration of methods that will overall reduce reliance on chemicals.

MATERIALS AND METHODS

Review of state and federal legislation

Current legislation for chemical use in aquatic situations in Australia (both state and federal) and the USA, Canada, New Zealand and Europe was reviewed. Key individuals from state and federal agencies involved in aquatic weed management participated in a workshop to outline aquatic weed issues, including the development of a list of herbicides that could be used in aquatic systems, a review of data limiting their approval in Australia and a risk analysis of chemicals used in potential aquatic herbicides. A network reference group was established from the participants to help develop a list of herbicides that could be used in aquatic environments.

Sifting the aquatic herbicide list

Trigger values (ANZECC 2000), the environmental risk quotient (RQ) (EPHC 2009) for singular application of chemicals and the Pesticide Toxicity Index (PTI) (Munn *et al.* 2006) for the application of multiple chemicals were used to summarise complex information on potential herbicides into simple numerical or textual ratings for resource managers.

The ANZECC trigger values help determine the suitability of water quality for human use, food production or aquatic ecosystem health. Water quality that does not meet the guidelines would trigger management action involving a more accurate investigation into the safety of that particular water use and the need to remedy the problem. Currently, only 22 herbicides have assigned trigger values and of these, only nine chemicals (2,4-D, acrolein, amitrole, bensulfuron, diquat, diuron, glyphosate, metsulfuron and simazine) have relevance to aquatic weed management in Australia. Trigger values were calculated for additional herbicides of interest for aquatic use.

The RQ is the ratio between the Predicted Environmental Concentration (PEC) of the active ingredient in the aquatic environment and an Effect Level (EL) (RQ = PEC/EL). The effect level or endpoint is the acute toxicity level for the most relevant sensitive species. Two measures are used: an LC_{50} (the concentration of a pesticide where 50% of the organisms die) or EC_{50} (the concentration of a pesticide at which 50% of the test organism exhibits a response; typically this involves an effect on growth or behaviour, such as immobilisation). The RQ is used to assess whether the value exceeds any predetermined threshold levels of concern and if the risk is acceptable, unacceptable or requires management in order to make the risk acceptable.

The PTI is a simple method for evaluating the potential toxicity to aquatic organisms for chemicals that co-occur in the water, using the concentration addition model. It is a useful tool to compare or rank the potential toxicity of multiple chemicals that are proposed to treat water bodies containing a complex suite of weeds from different taxa in different profiles within the water column. A limitation of the PTI is the assumption that chemical toxicity is additive among chemicals and that there are no chemical interactions that increase overall toxicity. This situation may not always apply in aquatic systems with chemical mixtures having different modes of action.

The ecotoxicology database (ECOTOX) (USEPA 2012), created and maintained by the USEPA and the Australasian Ecotoxicology Database (Warne *et al.* 1998), was the main source of toxicity endpoints for aquatic organisms used in the project. The main EC_{50} endpoint used for crustaceans, insects, invertebrates and molluscs was immobilisation and for *Lemna* spp., EC_{50} endpoints were based on population effects measured as changes to growth and photosynthesis. EC_{50} for algae were derived from population and growth effects measured as changes in abundance, biomass, density, population growth rates, population changes and photosynthesis. The LC_{50} endpoint for each of the nine taxonomic groups (algae, amphibians, crustaceans, fish, insects, invertebrates, molluscs, plankton and plant (refers to *Lemna* spp. only)) was based on empirical mortality data. The number of species with chemical toxicity data within each taxonomic group was respectively 57, 12, 90, 103, 23, 19, 28, 1 and 3 species. No taxonomic group contained data on all 38 chemicals reviewed. Chemicals with toxicity data within each taxonomic group varied from 2 to 37 chemicals (24 chemicals for algae, 12 for amphibians, 31 for crustaceans, 37 for fish, 10 for insects, 2 for invertebrates, 10 for molluscs and 8 chemicals for the *Lemna* spp.). The review resulted in a total of 1235 entries (not included in this report due to the size).

RESULTS

Sifting the aquatic herbicide list

Thirty-eight herbicides are either registered or under a minor use permit for use in aquatic areas globally. To enable short listing of chemicals for potential use in Australia, index values were established from the three different measures for all 38 chemicals. Two thirds of these actives are available in Australia though not necessarily registered for use in aquatic systems. Only five herbicides overlap between the US and Australia: 2,4-D, carfentrazone, copper, diquat and glyphosate. In the US, eight additional actives were identified as registered for use in aquatic environments (AERF 2005), with a further three actives under an experimental use permit issued by the US-EPA (Haller and Stocker 2003). Period of registration in the US for these aquatic herbicides ranges from years to decades (endothal 1959, fluridone 1986, triclopyr 2002, imazapyr 2003, penoxsulam 2007, imazamox 2008, flumioxazin 2010 and bispyribac 2010) (Netherland 2010).

DISCUSSION

The use of indices or trigger values has a definite advantage as a communication tool. However, misuse could greatly reduce their usefulness. Indices are influenced not only by the concentration endpoints, but also by multiple aspects of the study design, such as the number of chemicals applied, detection limits, sampling frequency and timing of applications (Anderson 2008). As reporting tools, the indices provide a tool for screening for toxicity risk, and a mechanism that can determine if a sample is likely to be more or less toxic than another sample. Actual toxicity cannot be inferred from the indices as they are based on short-term laboratory experiments using EC_{50} or LC_{50} endpoints. They do not take into account long-term effects such as endocrine disruption or carcinogenicity. Also, environmental factors such as dissolved oxygen, dissolved organic carbon, pH, temperature, suspended sediment or dissolved organic carbon can modify the toxicity and availability of the chemical (Munn *et al.* 2006). Toxicity endpoints need to be updated regularly. Despite the limitations of the indices and trigger values, the use of short-term (acute) toxicity endpoints such as EC_{50} (sub-lethal response) or LC_{50} (mortality) and the predicted chemical concentration to be applied provide a mechanism to compare all 38 chemicals currently in use or trialled for aquatic environments world wide.

A further ten actives currently available in Australia (bensulfuron methyl, bentazone, clethodim, clomazone, flumioxazin, imazamox, imazapyr, quinclorac, sulfometuron and triclopyr) are potential candidates for trialling in aquatic environments, provided that an appropriate aquatic formulation is used and that environmental risk is managed. The chemicals bispyribac and penoxsulam would also provide a low risk or a risk that could be mitigated through management. Six chemicals (acrolein, copper, diuron, oxadiazon, oxyfluorfen and terbutryne) are the least preferred for use in aquatic systems based on the relative toxicity ratio.

More-in depth knowledge on each herbicide is needed to address potential issues limiting approval in Australia.

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