Diquat Summary – Use & Safety

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What is Diquat?

- Diquat (technical name diquat dibromide) is the active ingredient in Reglone®, a herbicide that has been used in New Zealand for over 40 years for both agricultural operations and lake-weed control.
- Reglone® (trade name) the only herbicide registered for use in New Zealand water bodies, contains 20% diquat dibromide.

How does it work?

- Diquat is a selective herbicide that controls most unwanted target weed species in freshwaters (e.g. elodea, egeria, lagarosiphon and hornwort). Many key native plant species are not affected (e.g. Chara and Nitella species) by diquat.
- When diquat comes into contact with the green parts of nuisance aquatic weeds (leaves and stems) it is rapidly absorbed producing peroxide that acts like a bleach desiccating plant tissue and disrupting cell membranes. Diquat affects the tissue it comes in contact with and is not moved around within the plant, so roots are not killed.
- Diquat is rapidly removed from the water and deactivated by adsorption onto inorganic and organic compounds in the water and sediments. This is why diquat is not always effective on nuisance weeds when the water is turbid, or the plants are covered with silt or an algal coating.

How is it applied?

- Diquat, applied in the 20% active ingredient formulation Reglone® can be applied from the air, by boat (either delivered onto the surface or injected beneath the surface by trailing hoses from the boom of the boat) or scuba diver. Choice of application method depends on several factors such as the state of the nuisance weed beds, the extent of the area to be treated and the logistics of the operation.
- Reglone® can be applied as a liquid, but a gelling agent is often added when targeting of submerged weed beds requires more effective placement (e.g. penetration of thermal layers in the water) or where slight water movements may compromise diquat contact time with target weed beds (e.g. relatively small weed beds within a large open lake). The gelling agent commonly used in New Zealand is guar gum, a common food thickener (e.g. ice cream) extracted from guar beans.
- Reglone® is usually diluted 1 part product to 2-3 parts water before boom application. Standard Reglone® application rate is 30 litres product to 1 hectare.

How toxic is Diquat?

- Like many products used around the home every day, diquat is toxic *in its concentrated form*. Water is used to dissolve diquat dibromide forming the other main ingredient. Minor additives include colour and odour compounds to aid identification and safety.
- All hazardous substances are classified under HSNO (Hazardous Substances & New Organisms Act 1996) according to the *type of hazard* and *scale of risk*. According to HSNO Reglone® *in its concentrated form* is one class less toxic than nicotine and two classes lower than caffeine and Paraquat.
- Relative toxicities are usually measured using the LD50, which is the dose of active ingredient required to kill 50% of test animals. The toxicity of various commonly used substances is compared in the following table.

Note: the lower the LD50 the more toxic the substance.

Substance	**Oral LD50 (mg/kg)**	**Use**	**Notes**
Cyanide	1	Rodenticide	
Strychnine	2	Rodenticide	
Nicotine	1-50		
Parathion	6-50	Insecticide	
Verapamil	108	Blood pressure	1 tablet = 120mg. 108mg x 70kg person = 63 tablets 10kg child = 7 tablets
Paraquat	58-150	Herbicide	
Chlorine	150-200	0.5-1.5ppm used in swimming pools.	Intense irritation to humans at 5ppm
Warfarin	185	Rodenticide	
Caffeine	192-355		
Diquat cation	214-420	Herbicide at 1ppm for weed control	Reglone = 20% diquat dibromide diquat dibromide = 54% cation (Toxicity of product = x 10 lower) Safe for skin contact at 30ppm
Asprin	350-1000	Pain killer	1 tablet = 300-500mg. 350 x 10kg child = 12 tablets
Salt	3000	Food additive	3000 x 70kg = 210 gms 70kg person = 1 cup (210gms) 10kg child = 3 Tbsns (30gms)

- Chronic toxicity studies (i.e. long-term exposure) on sheep and calves given diquat treated water at 20ppm (20 times rate used to kill aquatic weeds) as their only source of water for 8 months showed no toxic symptoms. Similarly, farm animals fed diets containing 100ppm diquat as dibromide salt (100mg/kg) for 1 month showed no effect and no significant diquat residues in meat or milk.

- A comparison of diquat to other well known substances in everyday use shows a much higher amount of diquat is required to achieve a toxic effect on test organisms compared to caffeine or nicotine.

How does diquat compare to chlorine in your swimming pool?

- A more relevant comparison can be made with chlorine, which is toxic at lower levels, but is used at similar rates in swimming pools as diquat is in lakes.
- Commercial formulation of Reglone® only contains 20% active ingredient, which means the toxicity of any commercially available product (e.g. Reglone®) is 5 times lower than the stated toxicity of the active ingredient (e.g. diquat dibromide).
- Apart from the water used in the commercial product (Reglone®) to dissolve and dilute the active ingredient, only small amounts of herbicide are added to water in order to kill aquatic weeds and this results in major dilution, which further reduces the risk.
- Reglone® is applied to the surface of weed infested waters at a rate of 30 litres/ha. The concentration used to kill target weeds in water is 1 ppm of diquat dibromide salt (or 0.54 ppm diquat cation) as the active ingredient once mixed through 0.5 m depth of treated water. Normally the depth of water containing treated submerged weeds will be several metres deep, so the concentration of active ingredient rapidly declines well below these levels. Because Reglone® contains only 20% diquat dibromide (or 10% diquat cation) then this is equal to only 1 drop of Reglone® product in 100,0000 drops (i.e., 10 litre) of water. This can be compared to walking only 1m along a 100 km journey.
- Reglone® is diluted 100,000 times by water to attain the concentration required for control of waterweeds (1 ppm of diquat dibromide salt in 0.5m of water). The safety of this concentration means that regulations in the USA allow direct water contact by swimmers immediately after treatment.
- A standard safety precaution used in calculating safe exposure to humans is to determine the 'No Adverse Observed Effect Level' (NOAEL) in a range of mammals. This is the smallest amount of active ingredient ever found to have any form of measurable effect (substantially less than the LD50 toxicity levels) and then to add a further safety factor of 100 times lower than the NOAEL level as the "safe" exposure level to humans. This safety factor is based on the precautionary assumption that humans could be up to 10 times more sensitive to pesticides than the any sensitive test animals, and that one person or subgroup of the population (such as infants and children) could be up to 10 times more sensitive to a pesticide than another.
- Chronic toxicity studies on dogs and mice typically show the NOAEL (No Adverse Observable Effect Level) to be between 0.5 and 4.5 mg/kg /day. However the most sensitive or conservative mammalian test results recorded are considered to be 0.22 mg/kg/day. This would be the equivalent of a 70 kg person consuming between 25 litres of diquat treated water (shortly after application). Using the conservative 1% of NOAEL rate, any human (child included) could safely drink 250 mls/day of diquat treated water (shortly after application) every day for life. Given that humans may typically consume around 2 litres of drinking water per day, then a further safety

margin is added so that an allowable daily consumption rate of 0.015 mg/l (15 ppb) diquat dibromide is used for drinking water standards.

- In New Zealand there is a 24-hour post-treatment prohibition period for swimming and drinking. This is a very conservative safety precaution based on the 1% NOAEL principle that is designed to prevent any possible mishap. Such a cautionary approach can be misinterpreted and heighten the public perception of risk with no foundation.

What about ecological effects?

- Diquat is considered non-toxic to fish at rates required to kill aquatic weeds. Trout are one of the most sensitive fish species known. For adult trout the LC50 (96 hrs exposure) is 6.1 – 18.7 ppm and for juveniles the chronic (21 day) LC50 is 2.9 ppm (diquat cation). For most other fish diquat must exceed 10 ppm for lengthy periods for mortality. A study was carried out on caged short-finned eels located in the Avon River (Christchurch) where diquat treatment occurred. Following a 3-week exposure, a series of physiological response biomarkers were measured and compared to eels upstream from the treatments. No effects of diquat treatment could be detected.
- The most sensitive known aquatic organisms to the diquat cation are amphipods (minute crustaceans <5mm long), which have an LC50 (96 hrs) of 0.05 ppm. However, using a 96 hour LC50 on aquatic organisms (such as trout and amphipods) is erroneous when compared to the half life of diquat in water.
- The concentration of diquat 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 or so of being applied. Adsorbed diquat has no residual toxicity, is not biologically active and is degraded slowly by microbial organisms within sediments.
- Diquat treatment of weed beds has been practiced in several of the Rotorua Lakes for the last 40 years, being first used in 1960. Several biological and ecological studies have found no detrimental changes in the resident fisheries or benthic organisms that are attributable to diquat toxicity. Sediment samples analysed from these lakes for potential accumulation of diquat residual found no measurable traces.
- In view of the rapid dispersion, adsorption and resulting exponential loss of diquat that occurs following application, undesirable toxic impacts would not be expected and there is no evidence of food chain accumulation from repeated use of diquat.

What about deoxygenation?

- By far the greatest hazard to aquatic life is de-oxygenation rather than diquat toxicity. All aquatic organisms require oxygen for life. Decomposition of weeds treated with diquat uses oxygen from the water during the decay process. The most important factors affecting dissolved oxygen depletion are the amount of biomass of decaying weed and the re-aeration rate. These are affected by the amount of open water, the degree of water movement and the water temperature. In warm water the oxygen

saturation capacity is less and decay rates are more rapid causing greater de- oxygenation than when water are cool.

- To minimise deleterious impacts associated with de-oxygenation it is preferable to treat weeds during spring or autumn months if large quantities of weed are expected to decay. Summer treatment is acceptable where applications are small relative to water volume. De-oxygenation need not be a threat to aquatic organisms if standard precautions are taken with respect to timing of treatment, application rates used and area to be treated at any one time. In the case of large lakes such as Lake Wanaka the area of weed beds to be treated is very small relative to the surrounding volume of water (this includes Paddock Bay), so there is little prospect of any significant deoxygenation occurring even if spraying were to be carried out in summer.
- Absence or lack of weed control can often lead to excessive weed cover that can detrimentally impact on the quality of water and associated aquatic life. Studies of weed choked drains and dense weed beds in lakes have shown dissolved oxygen levels can become lower than that required to support aquatic animals. Targeting of nuisance levels of weed species can be an acceptable and even desirable practice that can have both management and ecosystem benefits.