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# CONTROL OF ALGAE IN RICEFIELDS

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## BACKGROUND

Most rice farmers rank weeds and algal slime as their number one pest problem. For optimum rice yields, a wide range of algae that have been adapted to the aquatic environment must be controlled.

An integrated strategy comprising of the below dot points should be used to control weeds in rice:

- Preventive Weed Control
- Crop or Fallow Rotation
- Certified Seed
- Appropriate Water and Fertiliser Management
- Algicide and Herbicide Application.

Several species of single celled and filamentous algae are found in ricefields (*refer to Chart 1* for a detailed list of the main species found in southern New South Wales).

Algal blooms form large mats on the water surface and may suppress seedling emergence. After establishment of permanent water, flagellate algae quickly develop within 2 weeks. During this period, growth of planktonic diatoms and non-motile green algae also appear. As the young rice seedlings become established at the third leaf stage, they become heavily encrusted with diatoms and filamentous green algae. Excessive algal growth up to the five leaf stage of the rice seedling can impair seedling growth. Algal infestation in ricefields causes three physical effects on rice seedlings:

- The leaves of seedlings are shaded
- Algae form a barrier between the leaf surface and surrounding water
- Algal biomass drags down delicate leaf blades, slowing or preventing their emergence above the surface of the irrigation water.

The mass of attached algae and particulate matter may be 65 times that of the young rice seedling. Hence, the shorter the period of time that rice seedlings are submerged, the less potential for algal colonisation and interference with growth of the rice seedling.

Spirogyra floating in a pond. This algae forms extensive mats in ponds and rivers, occasionally blocking channels.



Spirogyra cell ( x 150).

# ALGAL SPECIES AND SUCCESSION IN RICEFIELDS

The composition of algal populations can be variable between sites and during the growing season. Typically, there is a seasonal succession of algae in irrigation water. The main classes of algae can be summarised as:

- Flagellates – free swimming, with one or more flagella (microscopic hairs)
- Diatoms – unicellular, planktonic, slime forming
- Non-Motile Green Algae – free floating, needle or spindle shaped
- Epiphytic Filamentous Green Algae – attached to leaf, cylindrical or spiral
- Matt-Forming, Filamentous Green Algae – green, thin filaments, one-cell wide
- Blue-Green Algae – single cell, planktonic.

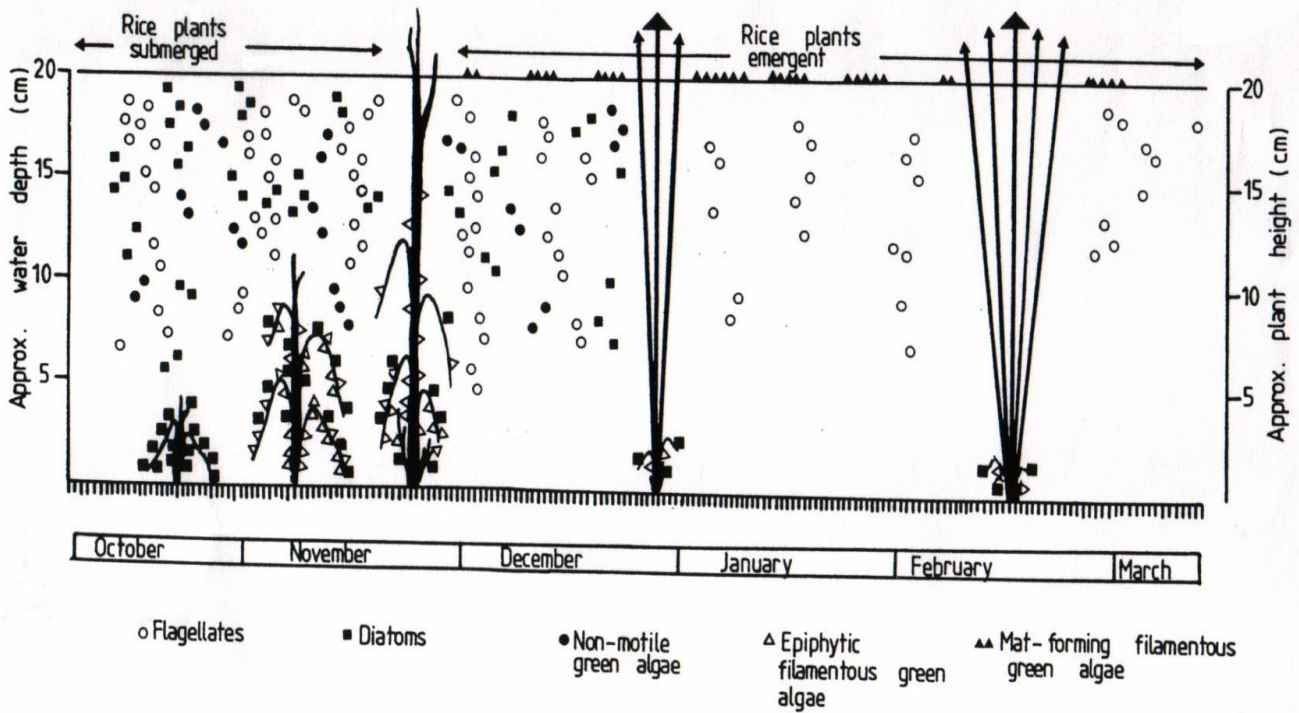
Further details of the various genera and their seasonal occurrence are given in *Chart 1*.

*Chart 2* shows the seasonal succession of algae in irrigation water associated with rice plants during the rice growing season.

**Chart 1. Types of Algae in Rice Irrigation Water in Southern NSW**

Algae Types	Algae Genera	ppm Cu required	Months of Growth
<b>Flagellates</b> Incl. Euglenoids, Chlamydomonads, Chrysophyceae, Cryptomonads, Dinoflagellates.	Trachelomonas –	–	October
	Euglena (S) 0.2 – 0.5		
	Chrysococcus –	–	To
	Mallomonas (S) 0.2 – 0.5		
	Sphaerellopsis –	–	March
Chlamydomonas (R) 0.5 – 1.0			
<b>Diatoms</b>	Melosira (VS) 0.2 – 0.5		October
	Nitzschia (S) 0.2 – 0.5		To
	Rhopalodia –	–	March
<b>Non-Motile Green</b> Incl. Desmids, Chlorococcales	Hyaloraphidium –	–	November
	Kirchnieriella (VR) 0.5 – 1.0		
	Scenedesmus (VR) 0.5 – 1.0		To
	Cosmarium (R) 0.5 – 1.0		
	Staurastrum (R) 0.5 – 1.0		December
	Xanthidium –	–	
Oocystis (R) 0.5 – 1.0			
<b>Epiphytic Filamentous Green</b>	Oedogonium –	–	November
	Mougeotia –	–	To
	Spirogyra (VS) 0.2 – 0.5		
	Zygenema (S) 0.2 – 0.5		December
	Coelastrum (S) 0.2 – 0.5		
<b>Matt-Forming Filamentous Green</b>			December To February
<b>Blue-Green</b>	Anabaena (VS) 0.2 – 0.5		January
	Oscillatoria (S) 0.2 – 0.5		To February

**Chart 2. The seasonal succession of algae in irrigation water associated with rice plants during the rice growing season**



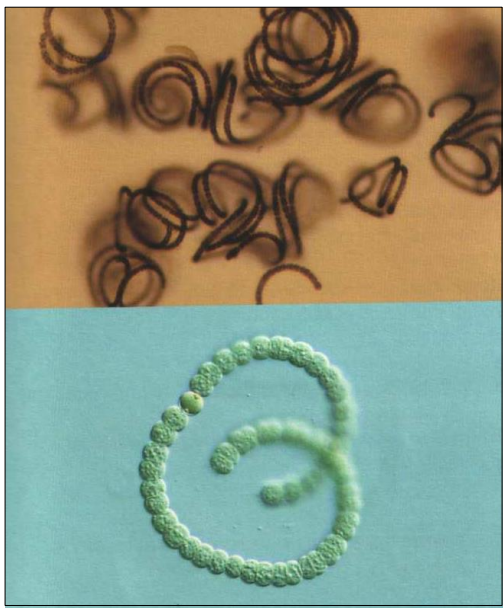
## SENSITIVITY OF ALGAE TO COPPER ALGICIDES

The genera of algae listed in Chart 3 are commonly found in irrigation waters and dams in Australia.

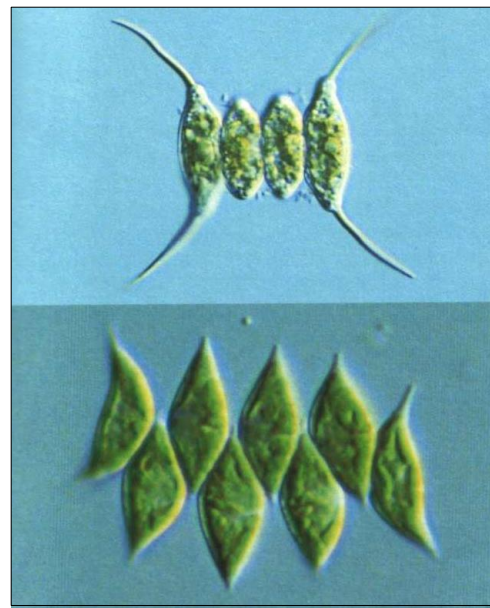
Free floating algae such as *Anabaena* and *Oscillatoria* are controlled using 0.2 to 0.5 ppm copper, depending on severity of growth. Filamentous and mat-forming algae such as *Spirogyra* and *Coelastrum* are controlled using 0.2 to 0.5 ppm copper.

More resistant non-motile green algae such as *Cosmarium*, *Scenedesmus* and *Kirchneriella* are controlled at the higher concentration of 0.5 – 1.0 ppm copper.

For optimum results, Cupricide should be applied at the first signs of an algal bloom. Apply Cupricide early in the day when conditions are calm. Water temperature should be greater than 15°C. Apply by aerial spray so that Cupricide is distributed evenly throughout the ricefield.



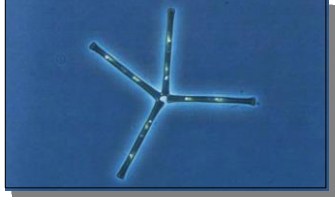
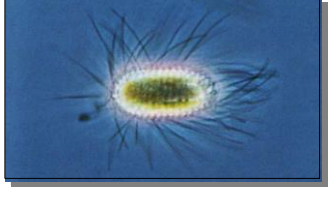


*Anabaena* is the most common toxic bloom-forming blue-green algae throughout Australia. (Pictured left x 100, x 450).



*Scenedesmus* is common in standing water, ponds, lakes and also on damp soil. (Pictured right x 1500, x 2000).

**Chart 3: Copper Concentration required for the Control of Susceptible (S) and Resistant (R) Algae**

Organism	Susceptible 0.2 – 0.5 ppm Cu	Resistant 0.5 – 1.0 ppm Cu
<p><b>Cyanophyceae (Blue Green)</b></p>  <p>Oscillatoria x 100</p>	<p>Anabaena Aphanizomenon Cylindrospermum Gloeotrichia Gomphosphaeria Microcystis Oscillatoria Plectonema Polycystis</p>	<p>Calothrix Nostoc Phormidium Symploca</p>
<p><b>Chlorophyceae (Green)</b></p>  <p>Oocystis x 1000</p>	<p>Botryococcus Closterium Coelastrum Drapamaldia Enteromorpha Gloecystis Hydrodictyon Microspora Spirogyra Tribonema Ulothrix Zygnema</p>	<p>Ankistrodesmus Chara Chlorella Cladophora Crucigenia Desmidium Golenkinia Nitella Oocystis Palmella Pithophora Scenedesmus Staurastrum Tetraedron</p>
<p><b>Diatomaceae (Diatoms)</b></p>  <p>Asterionella x 300</p>	<p>Asterionella Fragilaria Gomphonema Melosira Navicula Nitzschia Stephanodiscus Synedra Tabellaria</p>	<p>Achnanthes Cymbella Neidium</p>
<p><b>Protozoa (Flagellates)</b></p>  <p>Mallomonas x 800</p>	<p>Ceratium Cryptomonas Dinobryon Euglena Glenodinium Mallomonas Synura Uroglena Volvox</p>	<p>Chlamydomonas Eudorina Hawmatococcus Pandorina Peridinium</p>

# APPLICATION RATES OF CUPRICIDE IN RICEFIELDS

For maximum effect, Cupricide should be applied to newly flooded ricefields in the period 2 – 4 weeks after sowing, when the first signs of algae (green or brown slime) appear.

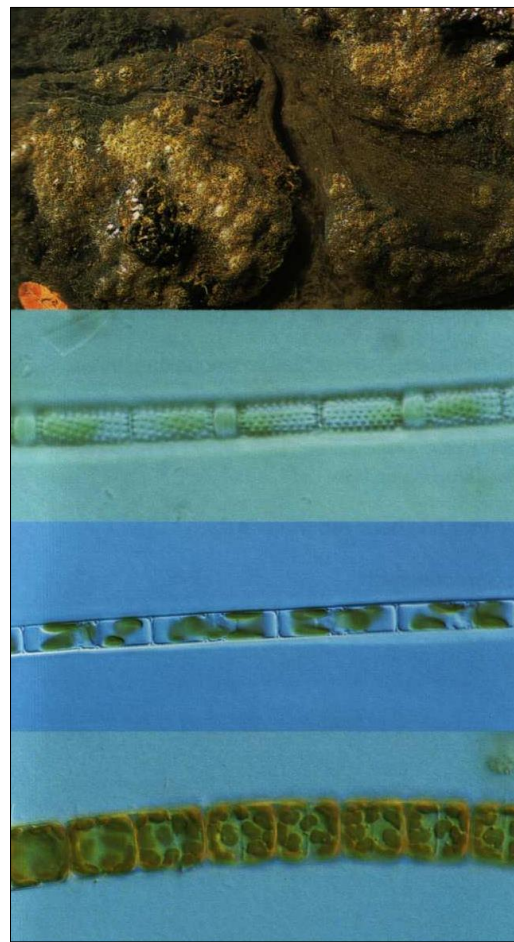
The copper concentration should be in the range 0.2 to 0.5 ppm for susceptible algae (S) and 0.5 to 1.0 ppm for resistant algae (R) – refer to Chart 1 for a list of frequently encountered genera. To obtain the maximum available copper concentration, apply Cupricide when the water level is lowest (5 – 15 cm depth). The activity of Cupricide in controlling algae will be observed within 2 – 5 days after application.

The following Table gives quantities of Cupricide (Litres/Hectare) required at various depths of water to provide 0.2 to 1.0 ppm copper.

Water Depth Cm	Water Volume Ml/Ha	Litres Cupricide / Ha		
		0.2 ppm Cu	0.5 ppm Cu	1.0 ppm Cu
5	0.5	1	2.5	5
10	1.0	2	5	10
15	1.5	3	7.5	15

Aulacoseira attached to rocks in a stream (top)  
x 1000 (upper-middle & lower-middle).

Aulacoseira was previously called Melosira,  
x 400 (bottom) which has now been defined.





# COMPATIBILITY OF CUPRICIDE WITH HERBICIDES

Cupricide has been tested for physical and chemical compatibility with selected herbicides commonly used to control rice weeds (barnyard grass and Dirty Dora).

Tank Mixes were prepared in proportions recommended for 100 Litres of spray solution. These solutions are based on the highest concentrations of herbicides recommended by the manufacturer and can be used for aerial spray application at the rate of 10 Litres per Hectare.

Typically, 20 Litres of Cupricide is added to 100 Litres total tank mix and this solution will be sufficient to treat 10 Hectares when the water depth is 5 – 10 cm. More dilute solutions in water can be prepared by following the instructions on the label.

Cupricide was found to be compatible with Molinate, Londax®, Saturn® and Taipan®. Cupricide is **not** compatible with the insecticide Chlorpyrifos. Further details of the Tank Mix proportions are shown in Chart 4.

**Chart 4: Compatibility Tests with Cupricide and Selected Herbicide / Insecticides**

Herbicide	Group	Trade Names	Tank Mix* 100 Litres	pH	Test Results
Molinate 960 g/L	E	Ordram EC Molinate 960	37 L Herbicide 20 L Cupricide	8.7	Compatible
Thiobencarb 800 g/L	H	Saturn EC	37 L Herbicide 20 L Cupricide	8.7	Compatible
Clomazone 480 g/L	F	Magister	6 L Herbicide 20 L Cupricide	8.6	Compatible
Benzofenap 300 g/Kg	F	Taipan	20 Kg Herbicide 20 L Cupricide	8.6	Compatible
Bensulfuron Methyl 600 g/Kg	B	Londax DF	1 Kg Herbicide 20 L Cupricide	8.6	Compatible
MCPA 250 g/L	I	MCPA 250	25 L Herbicide 20 L Cupricide	9.1	Compatible
Fibronil 500 g/L	1	Cosmos	0.25 L Insecticide 20 L Cupricide	8.6	Compatible
Prodione	B	Rovral	0.1 L Herbicide 20 L Cupricide	8.6	Compatible
Chlorpyrifos 500 g/L	3	Lorsban Chlorfos Iban	1.5 L Herbicide 20 L Cupricide	8.4	Incompatible

\*Tank Mix is designed for Aerial Spray at 10L per Hectare

20 Litres of Cupricide



200 Litres of Cupricide

Cupricide is also available in other sizes of 1 Litre, 5 Litres & 1000 Litres.

# CUPRICIDE – ENVIRONMENTAL CHEMISTRY AND FATE

## Environmental Transport and Information

Copper compounds such as Cupricide are intentionally applied to water to kill algae. Several processes influence the fate of copper in the aqueous environment. These include complex formation, sorption to hydrous metal oxides, clays and organic materials and bioaccumulation.

Information on the physiochemical forms of copper (speciation) is more informative than total copper concentrations. Much of the copper discharged to water is in particulate form and tends to settle out, precipitate out or be adsorbed by organic matter, hydrous iron, manganese oxides and clay in the sediment or water column.

In the aquatic environment the concentration of copper and its bioavailability depend on factors such as water hardness and alkalinity, ionic strength, pH and redox potential, complexing ligands, suspended particulate matter and carbon and the interaction between sediments and water.

Most copper deposited in soil is strongly adsorbed and remains in the upper few centimetres of soil. Copper adsorbs to organic matter, carbonate minerals, clay minerals, hydrous iron and manganese oxides. The greatest amount of leaching occurs from sandy acidic soils. In the terrestrial environment a number of important factors influence the fate of copper in soil. These include the nature of the soil itself, pH, presence of oxides, redox potential, charged surfaces, organic matter and cation exchange.

Bioaccumulation of copper from the environment occurs if the copper is biologically available. Accumulation factors vary greatly between different organisms, but tend to be higher at lower exposure concentrations. Accumulation may lead to exceptionally high body burdens in certain animals (such as bivalves) and terrestrial plants (such as those growing on contaminated soils). However, many organisms are capable of regulating their body copper concentration.

## Environmental Levels of Copper

Copper levels in seawater of 0.15 µg/Litre and in fresh water of 1 – 20 µg/Litre are found in uncontaminated areas. Sediment is an important sink and reservoir for copper. Background levels of copper in natural freshwater sediments range from 16 to 5000 mg/Kg (dry weight). Copper levels in marine sediments range from 2 – 740 mg/Kg (dry weight). In anoxic sediments copper is bound strongly by sulphide and therefore not bioavailable.

Median copper concentrations in uncontaminated soil were reported to be 30 mg/Kg (range 2 – 250 mg/Kg). Copper is accumulated by plants, invertebrates and fish. Higher concentrations of copper have been reported in organisms from copper contaminated sites than those from non contaminated sites.

## Effects of Copper on Humans

Copper is an essential element and adverse health effects are related to deficiency as well as excess. Copper deficiency is associated with anaemia, neutropenia and bone abnormalities but clinically evident deficiency is relatively infrequent in humans. Balance data may be used to anticipate clinical effects, whereas serum copper and ceruloplasmin levels are useful measures of moderate to severe deficiency but less sensitive measures of marginal deficiency.

For healthy, non-occupationally-exposed humans the major route of exposure to copper is oral. The mean daily dietary intake of copper in adults ranges between 0.9 and 2.2 mg. A majority of studies have found intakes to be at the lower end of that range.

The variation reflects different dietary habits as well as different agricultural and food processing practices used worldwide. In general, total daily oral intakes of copper (food plus drinking water) are between 1 and 2 mg/day, although they may occasionally exceed 5 mg/day.

## Effects of Copper on Biota

The adverse effects of copper must be balanced against its essentiality. Copper is an essential element for all biota, and care must be taken to ensure the copper nutritional needs of organisms are met. At least 12 major proteins require copper as an integral part of their structure.

It is essential for the utilisation of iron in the formation of haemoglobin and most crustaceans and molluscs possess the copper containing haemocyanin as their main oxygen-carrying blood protein. In plants copper is a component of several enzymes involved in carbohydrate, nitrogen and cell wall metabolism.

A critical factor in assessing the hazard of copper is its bioavailability. Adsorption of copper to particles and complexation by organic matter can greatly limit the degree to which copper will be accumulated and elicit effects. Other cations and pH can also significantly affect bioavailability.

In natural phytoplankton communities, chlorophyll *a* and nitrogen fixation were significantly reduced at copper concentrations of 20 µg/Litre and carbon fixation was significantly reduced at 10 µg/Litre. ED<sub>50</sub>s (72 hours) for algae, based on growth inhibition range from 47 to 120 µg Cu/Litre.

For freshwater invertebrates, 48 hours LC<sub>50</sub>s range from 5 µg Cu/Litre for a daphnid species to 5300 µg Cu/Litre for an ostracod. For marine invertebrates 96 hours LC<sub>50</sub>s range from 29 µg Cu/Litre for a bay scallop to 9400 µg Cu/Litre for the fiddler crab. The acute toxicity of copper of freshwater and marine fish is highly variable. For freshwater fish 96 hours LC<sub>50</sub>s range from 60 µg Cu/Litre for Chinook salmon to 1400 µg Cu/Litre for grey mullet.

Tolerance to copper has been demonstrated in the environment for phytoplankton, aquatic and terrestrial invertebrates, fish and terrestrial plants. Tolerance mechanisms which have been proposed in plants include binding of metal to cell wall material, presence of metal-tolerant enzymes, complex formation with organic acids with subsequent removal to the vacuole, and binding to specialised thiol-rich proteins or phytochelatins.

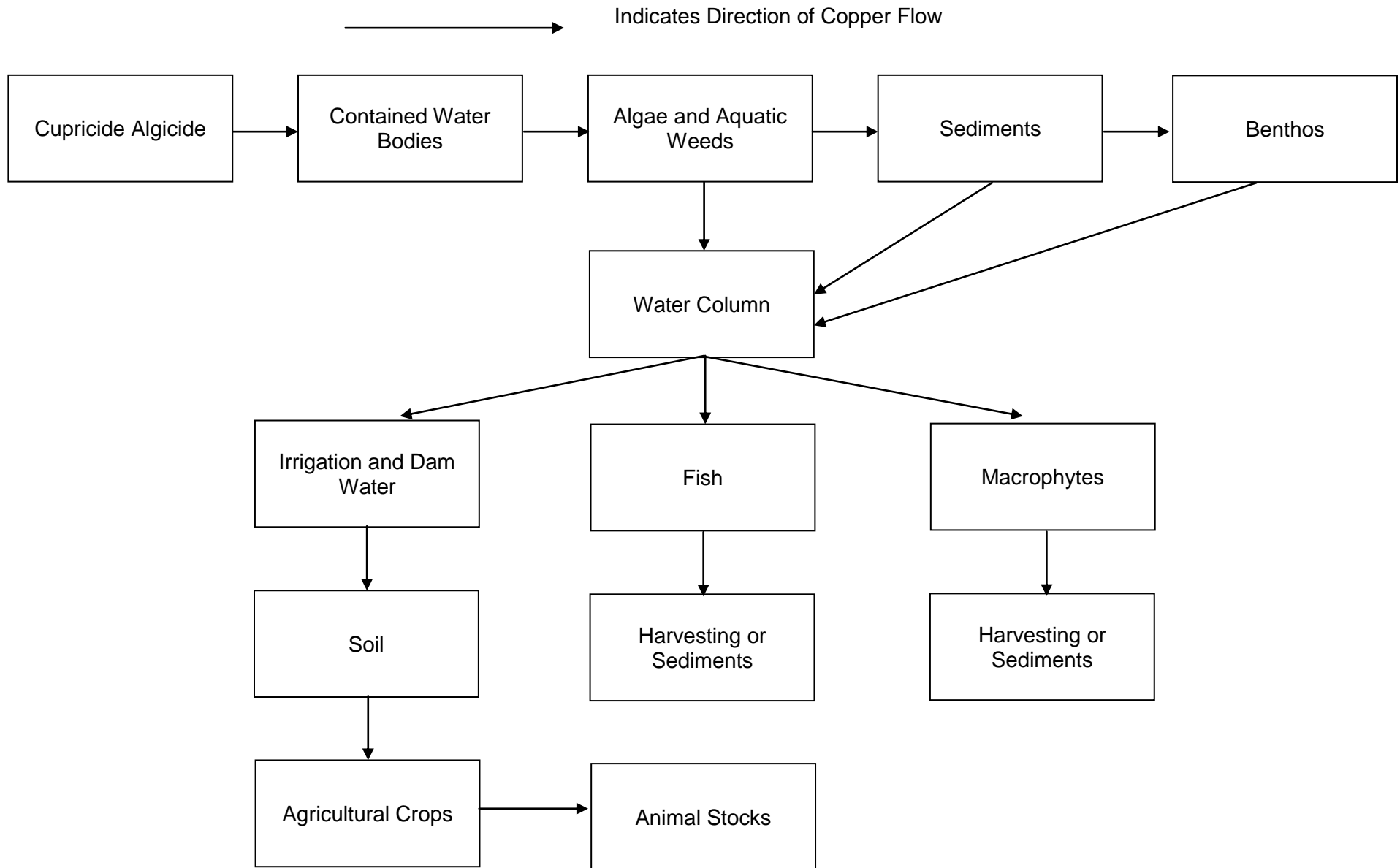
## Environmental Effects

Protection of aquatic life in water with high bioavailability will require limiting total dissolved copper to some concentration less than 10 µg/Litre; however, the appropriate concentration limit will depend on the biota and exposure conditions at sites of concern and should be set based on further evaluation of all relevant data.

*At many sites, physiochemical factors limiting bioavailability will warrant higher copper limits. Regulatory criteria should take into account the speciation of copper if dischargers can demonstrate that the bioavailability of copper in the receiving water can be measured reliably.*

*Because copper is an essential element, procedures to prevent toxic levels of copper should not incorporate safety factors that result in recommended concentrations being below natural levels.*

**Chart 5: Biogeochemical Cycle of Copper from Cupricide Algicide**



# CUPRICIDE SAFETY DIRECTIONS AND TOXICOLOGICAL DATA

Cupricide has been registered by the NRA for use as an algicide in lakes, potable water reservoirs, farms, fish and industrial ponds, fish hatcheries, rice paddies, raceways and irrigation systems. The product is designed to be diluted at 1:5 in water, and applied to the water surface of the area to be treated.

## Safety Directions

The safety directions on the label have been developed based on current standards issued by TGA and NOHSC and known hazards of copper sulphate and its chelate compounds. These standard hazard statements are:

*Harmful if swallowed. Will irritate eyes, nose, throat and skin. Avoid contact with eyes and skin. If product on skin, immediately wash area with soap and water. If product in eyes, wash it out immediately with water. Wash hands after use.*

## Toxicology

Copper sulphate is currently on the NRA TGAC exempt list. It is included in Schedule 5 of the SUSDP for concentrations less than 15%, except in preparations for internal use, or in other preparations containing 5% or less copper sulphate. It is included in Schedule 6 of the SUSDP, except when in Schedule 5, in preparations for internal use or in other preparations containing 5% or less copper sulphate. No Allowable Daily Intake has been established for copper sulphate.

The toxicity of copper sulphate has been considered previously. It has an oral LD<sub>50</sub> of 300 mg/Kg body weight in the rat, while in the mouse the LD<sub>50</sub> is 50 mg/Kg body weight. Clinical signs observed included salivation, vomiting, diarrhoea, gastric haemorrhage, tachycardia, hypotension, haemolytic crisis, convulsions and paralysis.

Copper sulphate is a severe skin and eye irritant, and can cause allergic contact dermatitis in susceptible individuals. Long term dosing with copper sulphate in a range of species produced effects relating to irritation of the stomach, decreased body weight gain, liver effects and anaemia.

No toxicological data relating to Cupricide have been established. No Allowable Daily Intake has been established for copper, however it is ubiquitous in the environment and forms part of the normal diet.

The proposed use pattern of Cupricide should result in copper levels at the time of application of up to 1 mg/L in the treated water. This is equal to the National Water Quality Management Strategy Australian Drinking Water Guidelines recommended levels for aesthetic quality (1 mg/L), and half the Drinking Water Guidelines recommended level for health (2 mg/L). As reapplication is only recommended at a minimum of 14 day intervals, use of Cupricide is unlikely to produce copper levels of concern in drinking water.

# TIMING AND MANAGEMENT OF CUPRICIDE APPLICATION

Cupricide can be included in the Program for the management of aquatic weeds and algae in ricefields. Algal growth will be most damaging when the rice seedlings are in the submerged state, up to the 3 leaf stage. During this period, typically October – November, the leaves of the seedling can be colonised by diatoms and filamentous green algae, resulting in shading of the leaf and deprivation of nutrients. Cupricide should be applied in the early stages of algal growth to control further development of the algal population. The most effective time is in the period up to the 3 leaf stage or earlier, as required. An illustration of the timing and management of Cupricide application is shown in Chart 6.

**Chart 6: Timing and Management of Cupricide Application For Algae In Ricefields**

PROGRAM	STAGE OF RICE GROWTH
<p>A) <b>STANDARD MOLINATE</b> Molinate plus Londax® plus MCPA</p>	<p><b>MOLINATE</b> Apply when Barnyard grass is at 0 – 4 leaf stage. Avoid application at sowing time</p> <p><b>CUPRICIDE – Apply when algae (brown/green slime) first appear 20 – 30 days after sowing.</b></p> <p><b>LONDAX®</b> Apply when weeds are small, up to the 3 leaf stage.</p>
<p>B) <b>STANDARD SATURN®</b> Saturn® plus Londax®, plus MCPA</p>	<p><b>CUPRICIDE – Apply when algae (brown/green slime) first appear 20 – 30 days after sowing.</b></p> <p><b>LONDAX®</b> Apply when weeds are small, up to the 3 leaf stage.</p> <p><b>SATURN®</b> Apply when Dirty Dora is in the 0-2 leaf stage, and barnyard is in the 0-3 leaf stage. Rice <u>must</u> have secondary (fibrous) roots.</p>
<p>C) <b>MOLINATE PRIMER</b> Molinate plus Saturn® plus Londax®, plus MCPA</p>	<p><b>MOLINATE</b> Apply 1-1.5 L to newly flooded field free of weeds before rice sowing.</p> <p><b>CUPRICIDE – Apply when algae (brown/green slime) first appear 20 – 30 days after sowing.</b></p> <p><b>SATURN®</b> Apply when Dirty Dora is in the 0-2 leaf stage, and barnyard is in the 0-3 leaf stage. Rice <u>must</u> have secondary</p> <p><b>LONDAX®</b> Apply when weeds are small, up to the 3 leaf stage.</p>
<p>D) <b>SPLIT SATURN</b> Saturn® plus Saturn® plus Londax®, plus MCPA</p>	<p><b>SATURN®</b> Apply 1-1.5 L to newly flooded field free of weeds before rice sowing.</p> <p><b>CUPRICIDE – Apply when algae (brown/green slime) first appear 20 – 30 days after sowing.</b></p> <p><b>SATURN®</b> Apply when Dirty Dora is in the 0-2 leaf stage, and barnyard is in the 0-3 leaf stage. Rice <u>must</u> have secondary (fibrous) roots.</p> <p><b>LONDAX®</b> Apply when weeds are small, up to the 3 leaf stage.</p>
<p>E) <b>TAIPAN</b> Taipan® plus Molinate plus MCPA N.B. Taipan® is approved for commercial Field evaluation by Permit PER1693</p>	<p><b>MOLINATE</b> Apply when Barnyard grass is at 0 – 4 leaf stage. Avoid application at sowing time</p> <p><b>TAIPAN®</b> Apply to newly flooded field within 10 days of the commencement of flooding.</p> <p><b>CUPRICIDE – Apply when algae (brown/green slime) first appear 20 – 30 days after sowing.</b></p>
<p>F) <b>COMMAND</b> Command® plus Londax® plus MCPA N.B. Command® is approved for commercial Field trial evaluation by Permit PER1874</p>	<p><b>COMMAND®</b> Apply to newly flooded fields, free of weeds before flooding up to 3 leaf stage barnyard grass.</p> <p><b>LONDAX®</b> Apply when weeds are small, up to the 3 leaf stage.</p>