

Control of Algae using Barley Straw

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Algae cause a number of problems in water. They impede flow in drainage systems; block pumps and sluices; interfere with navigation, fishing and other forms of recreation; cause taint and odour problems in potable waters; block filters and; in some instances, create a health hazard to humans, livestock and wildlife. These problems are increasing because nutrient concentrations in water are rising as a result of human activity and natural processes. There is simultaneous and growing demand world-wide for improvements in water quality. The need to control algae, therefore, is increasing for environmental, recreational and public health reasons. Because of their small size and rapid growth rates, unicellular algae are difficult to control by methods used for other aquatic plants. Cutting and other forms of mechanical control can help to reduce problems with filamentous algae but are of very limited use.

Algae are susceptible to herbicides, but this approach is unpopular in some waters on environmental or public health grounds. Furthermore, herbicides which control algae also kill higher plants so that, although the water is cleared temporarily of all plants, once the herbicide has gone from the water, the regrowth of algae is not restricted by competition from the higher plants and the problem may worsen in subsequent years. The Centre for Aquatic Plant Management developed a novel method of controlling algae, which overcame many of these problems. The application of barley straw to water and has been tested in a wide range of situations and in many countries throughout the world and has proved to be very successful in most situations with no known undesirable side-effects. It offers a cheap, environmentally acceptable way of controlling algae in water bodies ranging in size from garden ponds to large reservoirs, streams, rivers and lakes.

Despite the simplicity of the idea, experience has shown that there are a number of basic rules that must be followed to ensure that the straw works successfully. The purpose of this Information Sheet is to provide practical advice on the optimum ways of using straw.

HOW STRAW WORKS: In order to use straw effectively, it is necessary to understand something of how the process works. When barley straw is put into water, it starts to decompose and during this process chemicals are released which inhibit the growth of algae. Rotting is a microbial process and is temperature dependent, being faster in summer than in winter. It may take 6-8 weeks for straw to become active when water temperatures are below 10 °C but only 1-2 weeks when the water is above 20 °C. During this period, algal growth will continue unchecked. Once the straw has started to release the chemical it will remain active until it has almost completely decomposed. The duration of this period varies with the temperature and the form in which the straw is applied and this will be discussed in more detail later. The straw should remain active for between four and six months, after which its activity decreases rapidly.

The details of the exact mechanism by which straw controls algae has not been fully investigated, but it is generally accepted that the process may occur as set out below. Only a few of the compounds released from straw have been identified, the majority are known to be non-toxic while some may have slight toxic effects at the concentrations detected.

It is likely that a combination of factors results in the anti-algal activity generated from decomposing straw.

1. When straw is first placed in water, the soluble components of the straw are washed out, causing water to turn a brown colour. These compounds have not been identified, but they are likely to be a mixture of carbohydrates and hemicelluloses. Bacteria are the most dominant micro-organism at this stage growing on carbohydrate reserves in the straw.
2. After about two weeks the dominant micro-flora changes to fungi. This is when decomposition of lignin and other cell wall components starts to occur by lignase enzymes produced by fungi.
3. When straw rots, the cell wall components decompose at different rates. Lignin is very persistent and is likely to remain and be released into the water as the other components decay. Decomposition of lignin leads to the production of a form of soluble lignin and other decomposition products. These decomposition products are likely to be transformed by bacterial and fungal enzyme activity before being released in to the surrounding water.
4. This mixture of compounds is transformed into fulvic and humic acids. These humic substances are more easily referred to as Dissolved Organic Carbon or DOC. DOC is a natural component of many freshwater and marine ecosystems. When light shines onto water which contains humic substances, in the presence of dissolved oxygen and sunlight hydrogen peroxide is eventually formed.
5. High molecular weight DOC absorbs sunlight energy and can pass this energy to dissolved oxygen molecules. The dissolved oxygen becomes unstable and decomposes into two singlet oxygen radicals. These are very short lived, of the order of 1 micro-second, but extremely reactive molecules. The singlet oxygen radicals form superoxide radicals and these decay to hydrogen peroxide in water. The hydrogen peroxide is slightly more stable and persists for approximately 2 days in freshwater. The presence of a continuous supply of the right form of DOC creates conditions whereby hydrogen peroxide and the other oxidizing agents can be continuously produced.
6. Concentrations of 2 ppm peroxide have been demonstrated to inhibit the growth of blue-green algae. Experiments have shown that sustained low concentrations of hydrogen peroxide can have a very similar effect on algae to that of straw.

There are various factors which affect the performance of straw and which support this hypothesis. It is important to take these factors into account to ensure successful treatment of algal problems with straw.

TYPE OF STRAW: Barley straw works more effectively and for longer periods than wheat or other straws and should always be used in preference to other straws. If barley is not available, other straws, including wheat, linseed, oil seed rape, lavender stalks and maize can be used as a substitute. The information in this leaflet describes the use of barley straw. If other straws are used, it is likely that the quantities applied and frequency of application may have to be increased. A wide range of barley straw varieties have been tested, including some grown organically and they all produced similar levels of anti-algal activity.

Hay and green plant materials should not be used because they can release nutrients which may increase algal growth. Also they rot very rapidly and may cause deoxygenation of the water.

SPEED OF EFFECT: Once the straw has become active, the time taken for control to become effective varies with the type of alga. Small, unicellular species which make the water appear

green and turbid, usually disappear within 6-8 weeks of straw application. The larger filamentous algae, often known as blanket weeds, can survive for longer periods and may not be controlled adequately in the first season if the straw is added too late in the growing season when algal growth is dense. It is preferable to add the straw very early in the spring before algal growth starts, and at least 3 months before an algal bloom is expected.

PRODUCTION OF ANTI-ALGAL ACTIVITY: Activity is only produced if the straw is rotting in well aerated conditions. Usually, there is adequate dissolved oxygen in water to ensure that the right decomposition products are produced by straw. However, if the straw is applied in large compact masses such as bales, or to very sheltered and isolated areas of water, there will be insufficient water movement through the straw, which will progressively become anaerobic (without oxygen). Under these conditions, only the surface layers of the straw will produce the chemical and so the majority of the straw will have no useful effect. In addition, anaerobic decomposition can produce chemicals which actually stimulate the growth of algae because the algae can use them as a source of carbon.

ABSORPTION AND INACTIVATION OF THE CHEMICAL: Products released from decomposing straw are very quickly absorbed by algae and are inactivated by mud and suspended sediment. Therefore, in waters which have high algal populations and are turbid with suspended mud, it is necessary to add at least double the recommended quantities of straw than in clear waters.

SELECTIVE EFFECT ON ALGAE Decomposing straw does not have any effect on higher plants. In our experiments, we have seen that the suppression of dense algal growth has allowed flowering plants (macrophytes) to recolonise waters which were previously dominated by algae. In several shallow lakes where straw was used, algae were replaced by higher plants which suppressed the subsequent growth of algae, so eliminating the need for further straw treatments.

EFFECTS ON INVERTEBRATE ANIMALS AND FISH: There are no reports of harmful effects on invertebrates or fish except in a few instances where excessive amounts of straw were applied to small ponds and the water became deoxygenated. These excessive doses were at least 100 times the doses recommended in this leaflet. In most instances, invertebrate populations increase substantially around the straw so providing a useful food source for fish. There is anecdotal evidence that, in fish farms and fisheries, straw treatments may be associated with improved gill function and fish health and vigour.

HOW MUCH STRAW DO I NEED?

In ponds, lakes and other still water bodies. We have found that the most important measurement in calculating the quantity of straw required is the surface area of the water. Surprisingly, the volume of the water does not appear to affect the performance of the straw as might be expected. This is because the majority of algal growth takes place in the surface layers of the water and so it is not necessary to measure the depth of the water or volume of the lake when calculating the quantity of straw required.

In still waters, the initial dose rate of straw should be 50 grams straw per square metre of water surface (gm^{-2}). The next dose rate should be about half the initial rate, or about 25 gm^{-2} . Once the algal problem has been reduced, further additions of straw should be made to prevent a recurrence of the problem. At this stage the dose can be reduced to the maintenance dose rate of 10 gm^{-2} .

On a hectare basis the dose rates are: initial 500 kg/ha ; subsequent 250 kg/ha and maintenance 100 kg/ha.

Conversion factors

*50 gm⁻² is equivalent to 2 ounces per square yard.
25 gm⁻² is equivalent to about 1 ounce per square yard
10 gm⁻² is equivalent to half an ounce per square yard
100 kg/ha is equivalent to 100 lbs per acre*

In turbid or muddy waters, it will always be necessary to add more straw than in clear, mud-free waters. It is clear from numerous trials in different types of water body that the quantity of straw needed can vary considerably and it is better to apply too much initially and then to reduce the quantity gradually each time straw is added until the dose has been reduced to 10g m⁻² or until algal growth starts to increase again when the dose should be increased to a previously effective level.

There is a dose rate level at which straw could cause problems by deoxygenating the water. This is caused by absorption of oxygen from the water by respiration of micro-organisms colonising the straw and by the chemical oxygen demand of the rotting process. However, barley straw decomposes slowly and the oxygen demand of micro-organisms is unlikely to cause any problems unless excessive amounts of straw (more than 550 gm⁻²) are applied.

Deoxygenation can occur as the result of natural processes especially in prolonged hot weather when the solubility of oxygen in water is reduced and biological oxygen demand increased. This deoxygenation is often caused by algal blooms and so the presence of straw, which prevents the formation of these blooms, can reduce the risk of deoxygenation.

Straw should not be applied during prolonged periods of hot weather to waters containing dense algal blooms as the combined oxygen demand from the algal bloom and the straw could temporarily increase the risk of deoxygenation which may lead to loss of some fish.

In flowing waters such as canals and drainage ditches: The same area basis calculation apply for applications of straw to slow flowing watercourses. The flow should not normally exceed 90 m/hr. The distance between straw masses should be no more than 50 m. The risk of causing deoxygenation in flowing waters is very small as the continuous supply of fresh oxygenated water will prevent any local deoxygenation around the straw.

HOW TO APPLY STRAW: The best way of applying straw varies with the size and type of water body. The best shape for a straw application is a cylindrical tube, as this reduces the surface area:volume ratio to a minimum. Straw sausages create the perfect shape for optimum decomposition. Waterland Management produces a straw sausage making machine. Suggestions as to the most appropriate methods for different types of water body are given below.

Slow flowing rivers, canals and drainage ditches: Straw should be applied in a loose form, either in gabions or as straw sausages. This increases the diffusion of oxygen to the site of decomposition and speeds up the process in this type of environment.

Garden Ponds: In still or very slow flowing water, bales should not normally be used as they are too tightly packed and do not allow adequate water movement through the straw. It is preferable to apply the straw in a loose form retained in some form of netting or cage. In small garden ponds where only a few grams of straw are needed, the straw can be put into a net bag,

nylon stocking or simply tied into a bundle with string. This can be attached to an anchor made of a stone or brick and dropped into the pond. However, as the straw becomes waterlogged, the net will gradually sink to the bottom. In this position, it will not work as effectively as it does near the surface and it is advisable to include some form of float in the net. Floats can be made of corks, polystyrene or small plastic bottles with well-fitting screw tops. Once the straw has rotted, the net, complete with float and anchor can be removed and used again. Waterland Management can supply small packets of straw for use in ponds. They will work best if anchored and attached to a float as described above.

Large ponds, lakes and reservoirs: For all large applications, straw sausages which can be made up to about 50m long containing some 150 kg of straw should be used. The length and size of each sausage is determined by the size and shape of the water body. It is advisable to incorporate floats at 1 m intervals within the netting to keep the straw near the surface when it becomes waterlogged. When first constructed, these sausages float well and can be towed behind a boat to the required position and anchored by rope to concrete blocks or sacks of gravel. It is preferable to anchor these straw sausages at only one end so that they can swing round to offer minimum resistance to wind or currents. Straw sausages can interfere with angling and boat traffic and their positioning needs to be carefully considered so as to have the minimum adverse effect on water users. Floats or buoys can be attached as markers to warn boat traffic or anglers of the position of the straw.

WHERE TO APPLY STRAW: It is always preferable to apply several small quantities of straw to a water body rather than one large one. This improves the distribution of the active factors throughout the water body. Straw works best if it is held near to the surface where water movement is greatest. This keeps the straw well oxygenated and helps to distribute the anti-algal chemical. In addition this ensures that the chemical is produced close to where the majority of the algae are growing and away from the bottom mud which will inactivate the chemical. The following aspects should be considered when deciding where to place the straw within a water body.

Small ponds: In small ponds where only a single net of straw is required, this should be placed in the centre of the pond. However, if there is an incoming flow of water, either as a stream or fountain, the straw net should be placed where there is a continuous flow of water over and through the straw. This will help to keep the straw oxygenated and spread the chemical throughout the pond.

Lakes and Reservoirs: In any body of still water, it can be assumed that the anti-algal chemical will diffuse outwards in all directions from each net of straw gradually being absorbed by algae and inactivated by mud until the concentration becomes too low to be effective. Beyond this distance, algal growth will continue unchecked and these algae will gradually drift back into the treated areas giving the impression that the straw is not working. In order to ensure that there are no areas within the water body unaffected by the straw, it is necessary to calculate how much straw is needed, how many nets should be employed and how far apart each net should be. Nets or sausages of straw should then be placed so that each net is roughly equidistant from its neighbours and from the bank.

Marine situations There has been very little research with straw in seawater and any treatments in these conditions should be regarded as experimental. Results from a very limited number of trials in salt water lagoons and artificial pools suggest that straw can work in salt as well as fresh water. However, it is very unlikely that it would have any effect on the large marine algae normally found on rocky shores or on kelp beds in the seas because of the problems of short persistence time and exposure. It is also unlikely that sufficient straw could be placed and held for long periods in the open sea.

The spacing of nets does not need to be exact. Practical considerations may influence the number of nets and their local placement. For example, it may be necessary to leave a wider corridor between some sets of nets to allow for adequate boat passage or angling purposes. Where possible any enlarged gaps between straw nets should be compensated for by decreasing the gaps between adjacent nets. If there are any inflowing streams, it is advisable to increase the number of nets near the inlet so that water flows through the straw and distributes the chemical into the lake. It is possible to compensate for this local concentration of straw nets near the inlet by reducing the numbers of nets near any outlet as the chemical released from these may be washed out of the lake. In an irregularly shaped water body, the preferred place for some of the nets is opposite any promontories or points where the nets will be exposed to maximum wind and wave action.

WHEN TO APPLY STRAW: Although straw can be applied at any time of year, it is much more effective if applied before algal growth begins. This is because the anti-algal agents released by the straw are more effective in preventing algal growth than in killing algae already present. Therefore, straw is best applied in the spring and autumn, when water temperatures are low. The straw will become active within a month and will continue to inhibit algal growth for about 6 months. However, rapid algal growth can take place once the straw has rotted away and so further applications should be made every 4 to 6 months.

It is important to note that the rate at which straw rots varies considerably and regular observations should be kept on the straw so that fresh straw can be added before the end of the 6 month period if necessary. It is not always possible to predict that an algal problem will occur and so it is sometimes necessary to treat an algal problem which has already developed.

Some algae, mainly the small unicellular species and the cyanobacteria (blue-green algae), can be controlled by adding straw to existing blooms. The time taken for the algae to be controlled depends on a number of factors, of which water temperature is probably the most important. At water temperatures above 20 °C straw has been effective in controlling algal blooms within 3-4 weeks, sometimes even faster.

Avoid applying straw during prolonged periods of hot weather as the combined effect of the dying algae and the rotting straw may increase the risk of deoxygenation.

At lower temperatures, the process is slower and it may take 8 - 10 weeks to control the algae but the risk of deoxygenation is then minimal. An advantage of lower temperatures is that the straw lasts longer too. In the north of Scotland straw has given good control for between 8 and 10 months, whereas in the south of England control usually lasts no longer than 6 months. This may also be related to the different nutrient concentrations in these two environments, with much higher dissolved nutrients being more often found in southern England.

When filamentous algae are the main problem, straw applied to dense floating mats will have very little useful effect unless combined with other treatments.

After the initial straw treatment, further additions will be required to prevent the return of the algae. Although a period of 6 months is suggested as the likely interval between straw applications, more frequent treatments may be necessary. It is inadvisable to wait until all the straw has rotted before making a second application as there will then be an interval when no chemical is being produced and rapid algal growth can take place. For the same reason, the old straw should not be removed for at least one month after the addition of the new straw. This allows time for the new straw to become active.

OTHER EFFECTS OF STRAW: During the numerous field trials in which straw has been applied in a number of forms and in a range of water bodies, various effects in addition to the control of algae have been noted. While these have not been investigated in any detail, they have occurred sufficiently frequently to be worth noting as possible consequences of using straw.

1. **Effects on other aquatic plants:** No direct effect of straw on aquatic vascular plants has been found in either laboratory or field experiments. However, in several trials where straw has successfully controlled algae, there has been a noticeable increase in the growth of submerged vascular plants. It is likely that this is a result of the loss of competition from the algae, which has allowed the vascular plants to recolonise water in which previously they were unable to compete with the algae. In some instances, the recovery of the vascular plants has been so marked that they, in turn, caused problems to water users and required some form of management. However, they are generally easier to control and less troublesome than the algae and so are more acceptable in most waters. In some instances, the recovery of the vascular plants has been so strong that they replaced the algal growth as the dominant plant form, so that subsequent treatment with straw was no longer needed.
2. **Effects on invertebrates:** It has been observed frequently that loose masses of well oxygenated straw provide a good habitat for aquatic invertebrates such as the Water Shrimp (*Gammarus* spp.). These invertebrates, mostly detrital feeders, breed and grow rapidly in the safe environment created by the straw and their numbers can increase by several orders of magnitude within a few months. As the straw gradually rots away and the numbers of invertebrates increases, individuals leave the safety of the straw and become prey to fish and waterfowl. Invertebrates are beneficial to water bodies as they help to decompose organic matter in the bottom; some of them graze on algae and aquatic plants and they form an important part of the food chain.
3. **Effects on fish and waterfowl** There have been a number of observations of improved growth, vigour and health of fish in waters treated by straw. One reason for this is likely to be the increased food supply in the form of invertebrate animals. Fish may also find it easier to find food in water that is not densely colonised by unicellular or filamentous algae. However, another possible explanation is that, by controlling the algae, the straw allows better light penetration to occur to deeper levels in the water so that photosynthesis can occur in a greater volume of the water body and so provide an improved environment for the fish.

The Game Conservancy has also noted that young ducklings require a diet that consists mainly of invertebrate animals. They found that adding straw to gravel pits significantly increased the survival of young ducklings. In a number of water bodies, ducks and other waterfowl have been observed to nest and roost on floating masses of straw. This has been particularly beneficial to these birds in waters subject to high levels of human interference and terrestrial predators as the floating straw masses are usually inaccessible from the bank. There have been a number of anecdotal reports that incidents of some fish diseases and parasites appear to have been reduced in fisheries and fish farms in which straw has been used.

SUMMARY

1. When algal problems occur in water bodies ranging from garden ponds to large reservoirs, lakes and rivers, barley straw offers an environmentally acceptable and cost-effective form of control.
2. Straw should be applied twice each year, preferably in early spring before algal growth starts and in autumn.
3. Particularly in static waters, the straw should be loose, through which water can pass easily and should be held in straw sausages or cages.
4. The minimum effective quantity of barley straw in still or very slow flowing water is about 10 gm⁻² but higher doses of up to 50 gm⁻² should be used initially in densely infested waters and muddy waters. Doses should be reduced to 25 then 10 gm⁻².
5. Straw should be supported by floats so that it does not sink to more than one metre below the surface, even when waterlogged. It is very important that straw does not come into contact with the muddy bottom.
6. If the straw starts to smell then it is not working and should be removed. This is caused by too much straw in too little water – take some of it out and put half as much in again in a looser form.
7. **Be patient, this is a natural process which takes time to work!**