INFORMATION SHEET 1: CONTROL OF ALGAE WITH BARLEY STRAW

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 has developed a novel method of controlling algae, which overcomes 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^{o}C but only 1-2 weeks when the water is above 20^{o}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.

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.

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

After about two weeks the dominant micro-flora change to fungi. This is when decomposition of lignin and other cell wall components starts to occur.

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. 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, hydrogen peroxide is eventually formed.

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 from 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 oxidising agents can be continuously produced.

Concentration of hydrogen peroxide of only 2 ppm peroxide have been demonstrated to inhibit the growth of 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.

TYPES 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 unavailable, 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, therefore, preferable to add the straw very early in the spring before algal growth starts.

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

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

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 probably inactivated by mud. 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 between 25 and 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^{-1}; subsequent 250 kg ha^{-1} and maintenance 100 kg ha^{-1}.

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^{-1} is equivalent to 90 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 500 gm^{-2}) are applied.

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

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. However, 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.

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. The remainder should be spaced between these, using the method of calculating the gaps shown above.

In flowing waters such as streams and rivers. We do not yet have sufficient information on the properties of straw to express a quantity of straw required in relation to the surface area or volume of water flowing down the stream. However, straw has been used effectively in these situations by placing quantities of straw at intervals along either bank of the river. The distance between straw masses has usually been between 30-50m and the size of each straw mass was chosen, for convenience, as about one bale (20kg).

Another technique has been used to increase flow, scouring out the bottom of the river creating fish feeding zones and controlling algae downstream. Gabions (wire mesh cages) are secured to the river bank and bottom and straw is placed in the gabions. This technique can be seen in the River Pang in the picture above. There is evidence of algal control from the upstream end of the gabions, this effect lasted for about 50 m downstream of the gabion.

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.

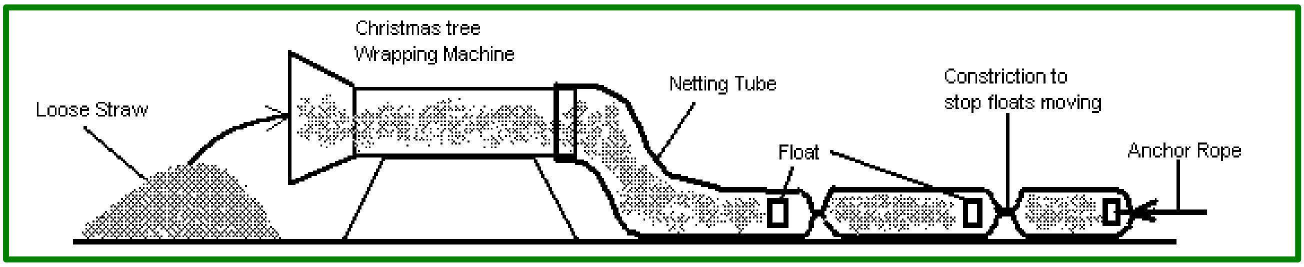
HOW TO APPLY STRAW

The best way of applying straw varies with the size and type of water body. Suggestions as to the most appropriate methods for different types of water body are given below.

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

Fast flowing rivers and streams. Straw can be applied in the form of bales because the flow of water will keep oxygen levels high enough to prevent the straw from becoming anaerobic. Only small bales (approximately 20kg) should be used. Bales can break up under the forces produced by fast flowing water and they should normally be wrapped with netting or chicken wire and securely anchored to the bank or posts driven into the river bed. Another way of applying straw which has worked effectively in flowing water is to place the straw in gabions (see above). These are wire mesh boxes (usually filled with stone for bank protection) but they work equally effectively as cages for straw. They have the additional advantage that they can be refilled as the straw rots away. Nets and loose woven sacks (e.g. vegetable storage sacks) filled with straw can also be used. In all instances, it is essential to ensure that the straw container is well anchored to the bank or to stakes in the bottom which will hold it in place during periods of high flow.

Slow flowing rivers. 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.

Some garden centres supply small packets of straw for use in ponds. They will work best if anchored and attached to a float as described above. See list of manufacturers at end of the document.

Large ponds, lakes and reservoirs: where larger quantities of straw are needed, bales should be broken up on the bank and the loose straw wrapped in some form of netting or wire. One of the simpler ways of wrapping large quantities of loose straw is to use one of the various forms of tubular netting normally sold for wrapping Christmas trees, constructing onion sacks and for other agricultural purposes. When used in conjunction with a tree wrapping machine they can be used to construct straw sausages which can be made up to about 20m long and contain some 50kg of straw. The length and size of each sausage is determined by the size and shape of the water body (described later). It is advisable to incorporate some floats 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

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

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. The steps involved in this calculation are explained overleaf with an example.

In rivers and streams From the point of view of getting maximum benefit from straw, it would be preferable to place the straw as a barrier across the flow of water. However, this is seldom possible because the force of the water would tend to wash the straw away and the straw would impede water

movement and boat traffic. Therefore, bales, straw nets or gabions should either be placed opposite each other in pairs or alternately along both banks. In fast flowing streams where there is little mud to absorb the chemical, the space between straw nets can be as much as 100 m (50 m if placed alternately) but in slow-flowing muddy watercourses, this space should be reduced to no more than 30 m. In very narrow streams, it may be necessary to place the straw close to the bank so as not to impede flow but in larger watercourses the straw should be as far out from the bank as possible. This makes it less subject to vandalism and damage from livestock and ensures that there is a good flow of water around and through the straw. Always ensure that the straw is well secured to the bank or to stakes in the bottom so that it does not get washed away during floods. It is usually necessary to consult the local water authority before applying straw to flowing water because they have the responsibility of ensuring that there is no danger to water supplies or other riparian users caused by partial obstruction to the flow

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

Table 1. Method for estimating amount of straw required.

Decision Step	Calculated example
Estimate the surface area of the lake	1.5ha (15,000 m^2)
Decide on the dose rate of straw required.	25 g/m^2
Multiply the area of the lake (in m^2) by the quantity of straw required per m^2	15,000 x 25 = 375,000 g 375,000 ? 1000 = 375 kg
To obtain the number of bales needed, divide the total weight of straw by the weight of bales Weights of bales should be checked.	375 ? 20 = 19 small bales
Decide on the weight of straw to be placed in each net. Nets should normally contain between 1kg (in small ponds and lakes) to 40kg (in very large lakes).	25 kg
Calculate the number of nets which will have to be constructed. Divide the total quantity of straw required by the weight in each net.	375 ? 25 kg = 15 nets
Calculate the area which will be treated by each net at the dose rate	25kg @ 25g/m^2 = 1,000 m^2
Calculate the radius of a circle with an area of the size calculated in 6 (above) using ?r^2.	?r^2 = 1,000 r = ?1,000 ?3.142 r = 17.85 m
The diameter of a circle of 1,000 m^2 is r x 2	diameter = 35.7 m
Decide on the most appropriate placement of the nets of straw in the lake so that each one is approximately 35m from its neighbour and 17m from the bank.	Usually a regular square grid pattern with centres at 35 m

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.

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.

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

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^{o}C straw has been effective in controlling algal blooms within 4-5 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 which will be described later. 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.

INTEGRATED AQUATIC WEED CONTROL

Filamentous algae are not easily controlled by straw once they have formed floating mats. However, they can be controlled by other methods. In some situations, filamentous algae can be raked out. However, many fragments will remain in the water and rapid regrowth is likely. To prevent this straw should be added about one month before the alga is raked out.

In other situations, herbicides (diquat or terbutryn) have been used in combination with straw. The herbicides control the algae but their effects may not persist for long once the herbicide has decayed or been otherwise dissipated from the water. By adding straw at the same time, or soon after the herbicide has been applied and maintaining a straw treatment regime as outlined above, the straw helps to prevent the return of the algae.

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 additional 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.

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.

Effects on invertebrates It has been observed frequently that loose masses of well oxygenated

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

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.

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.

Effects of straw in flowing waters When straw has been applied in flowing waters, either in the form of bales or in gabions, it has been noted that water is deflected around the straw and the accelerated flow caused silt and fine gravel to be washed away from the vicinity of the straw. In a small stream which had a very uniform depth, pairs of gabions containing straw were placed opposite each other and angled downstream so as to create a rapid flow between them. This caused the gravelly bed of the stream to wash out and so scour holes were formed. These were immediately colonised by trout which were the dominant fish species. The overall effect created by three pairs of gabions placed at approximately 100 m intervals was to create a pool and riffle environment which is usually considered to be preferable to a uniform channel for fish and aquatic life generally. In small streams, it is likely that careful placement of straw bales or gabions could be used to manipulate the location of silt deposits ensuring that an open channel is maintained and that silt beds are allowed to develop only in acceptable locations.

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

SUMMARY

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.

Straw should be applied twice each year, preferably in early spring before algal growth starts and in autumn.

Particularly in static waters, the straw should be loose, through which water can pass easily and should be held in nets, cages or bags.

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 g m^{-2} should be used initially in densely infested waters and muddy waters. Doses should be reduced to 25 then 10 gm^{-2}.

In rivers, masses of straw (bales or nets) should be spaced along the sides at intervals not more than 100m apart.

Straw should be supported by floats so that it does not sink to more than one metre below the surface, even when waterlogged.

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.

Be patient, this is a natural process which takes time to work!

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

LIST OF SUPPLIERS

Christmas Tree Wrapping Machines

Contimex Ltd
PO Box 94, Uckfield, East Sussex, TN22 5YZ
Tel: 01825 766135. Fax: 01825 760144

Netlon UK Ltd
Unit 3, Falconer Road, Haverhill, Suffolk, CB9 7XU
Tel: 01440 702394
L34 Loader

Plastic Mesh Tubing and Plastic Floats

Waterland Management Ltd
14 Buxton Avenue, Caversham, Reading, RG4 7BU
Tel: 0118 9482782, 07889 903203, www.water-land.co.uk

Straw Pads

Green Ways
Upper Norton Farm, Sutton Scotney, Nr Winchester, Hants SO21 3QF
Tel: 01962 761600 Fax: 01962 761696
E-mail sales@green-ways.co.uk
www.green-ways.co.uk

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

LIST OF CHEMICALS PRODUCED BY DECOMPOSING STRAW

Compound name
Acetic acid
3-Methylbutanoic acid
2-Methylbutanoic acid
Hexanoic acid
Heptanoic acid
Octanoic acid
Nonanoic acid
Decanoic acid
Dodecanoic acid
Tetradecanoic acid
Hexadecanoic acid
1-Methylnaphthalene
2-(1,1-Dimethylethyl phenol)
(1,1-Dimethylethyl)-4-methoxyphenol
2,6-Dimethoxy-4-(2-propenyl) phenol
2,3-Dihydrobenzofuron
5,6,7,7A-Tetrahydro-4,4,7A-trimethyl-2 (4H) benzofuranone
1,1,4,4-Tetramethyl-2,6-bis(methylene) cyclohexone
1-Hexacosene
11 unidentified

From : Everall, N.C and Lees, D.R. (1997). *Water Research,* **31**(3):614-620

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk

REFERENCES ON ALGAE AND STRAW

1. Barrett, PRF, Curnow, J & Littlejohn, J (1994) The control of diatom and cyanobacterial blooms in reservoirs using barley straw. Proceedings of Conference - Water 94. Elmia AB, P0 Box 6066, *550* 06, Jönköping.
2. Barrett,PRF, Curnow, J & Littlejohn, (1995) The control of diatom and cyanobacterial blooms in reservoirs using barley straw. Proceedings of EWRS Conference, 1994 Dublin. Hydrobiologia, 340:307-311.
3. Barrett,PRF, Curnow, J & Littlejohn, (1994) Potential uses of barley straw for control of algae and other nuisance organisms in water. Proceedings of Conference - Water 94. Elmia AB, P0 Box 6066, *550* 06, Jönköping
4. Barrett,PRF (1994) Monograph No. 59: Comparing glasshouse and field pesticide performance pp. 191-200. Field and laboratory experiments on the effects of barley straw on algae. British Crop Protection Council.
5. Barrett,PRF & Newman, JR (1993) The Control of Algae with Barley Straw. Paper 41,PIRA Conference proceedings, Straw – A valuable raw material. 20-22 April, 1993. PIRA International, Randalls Road, Leatherhead, Surrey KT22 7RU.
6. Barrett, PRF & Newman, JR (1992) Algal growth inhibition by rotting barley straw. British Phycological Journal, 27: 83-84
7. Caffrey, J. M. and Monahan, C. (1999) Filamentous algal control using barley straw. Hydrobiologia 415, 315-318.
8. Everall, NC & Lees, DR (1996) The use of barley straw to control general and blue-green algal growth in a Derbyshire Reservoir. Water Research, 30:269-276.
9. Everall, NC & Lees, DR (1997) The identification and significance of chemicals released from decomposing barley straw during reservoir algal control. Water Research, 31:614-620
10. Gibson, MT. Welch, I, Barrett, PRF & Ridge, 1 (1990). Barley straw as an inhibitor of algal growth: Laboratory studies. Journal of Applied Phycology 2: 241-248.
11. James, H (1992) Investigations into the use of straw to control blue-green algal growth. Foundation for Water Research, Allen House, The Listons, Liston Road, Marlow, Bucks. 5L7 lFD, UK
12. Martin D. & Ridge I. (1999) The relative sensitivity of algae to decomposing barley straw. *Journal of Applied Phycology* 11, 285-291.
13. Newman, JR, Barrett, PRF (1993) Control of *Microcystis aeruginosa* by decomposing barley straw. Journal of Aquatic Plant Management, 31: 203-206
14. Newman, JR (1994) Report on the control of growth of *Microcystis aeruginosa* by decomposing barley straw and the development of a bankside straw digester. LACR-Aquatic Weeds Research Unit, Broadmoor Lane, Sonning-on-Thames, Reading RG4 6TH, UK.
15. Newman, JR. Barrett, PRF, Cave, G (1993) The use of Barley Straw to control Algal Growth in Drainage Ditches: An Ecological Survey. Loughborough Conference Paper.
16. Pillinger, JM, Cooper, IA, Ridge, I, & Barrett, PRE (1992) Barley straw as an inhibitor of algal growth III: the role of fungal decomposition. Journal of Applied Phycology 4: 353-355
17. Pillinger, JM, Gilmour, I & Ridge, 1(1993) Control of algal growth by lignocellulosic material. FEMS Symposium on Lignin Biodegradation and transformation. Biotechnical Applications, Lisbon. April 18-21. pp. 57-58
18. Pillinger J.M., Cooper J.A., & Ridge I. (1994) Role of phenolic compounds in the antialgal activity of barley straw. *Journal of Chemical Ecology* 20, 1557-1569.
19. Pillinger J.M., Cooper J.A., & Harding C.J. (1996) Stable free radicals from plant litter decomposing in water. *Journal of Chemical Ecology* 22, 1001-1011.
20. Ridge, I & Barrett, PRF (1992) Algal control with barley straw. Aspects of Applied Biology 29. 457-462
21. Welch, I, Barrett, PRF, Gibson, MT & Ridge, 1 (1990) Barley straw as an inhibitor of algal growth I: studies in the Chesterfield Canal. Journal of Applied Phycology 2: 231-239

CAPM, CEH Wallingford, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB
Email: jone@ceh.ac.uk Web: www.capm.org.uk