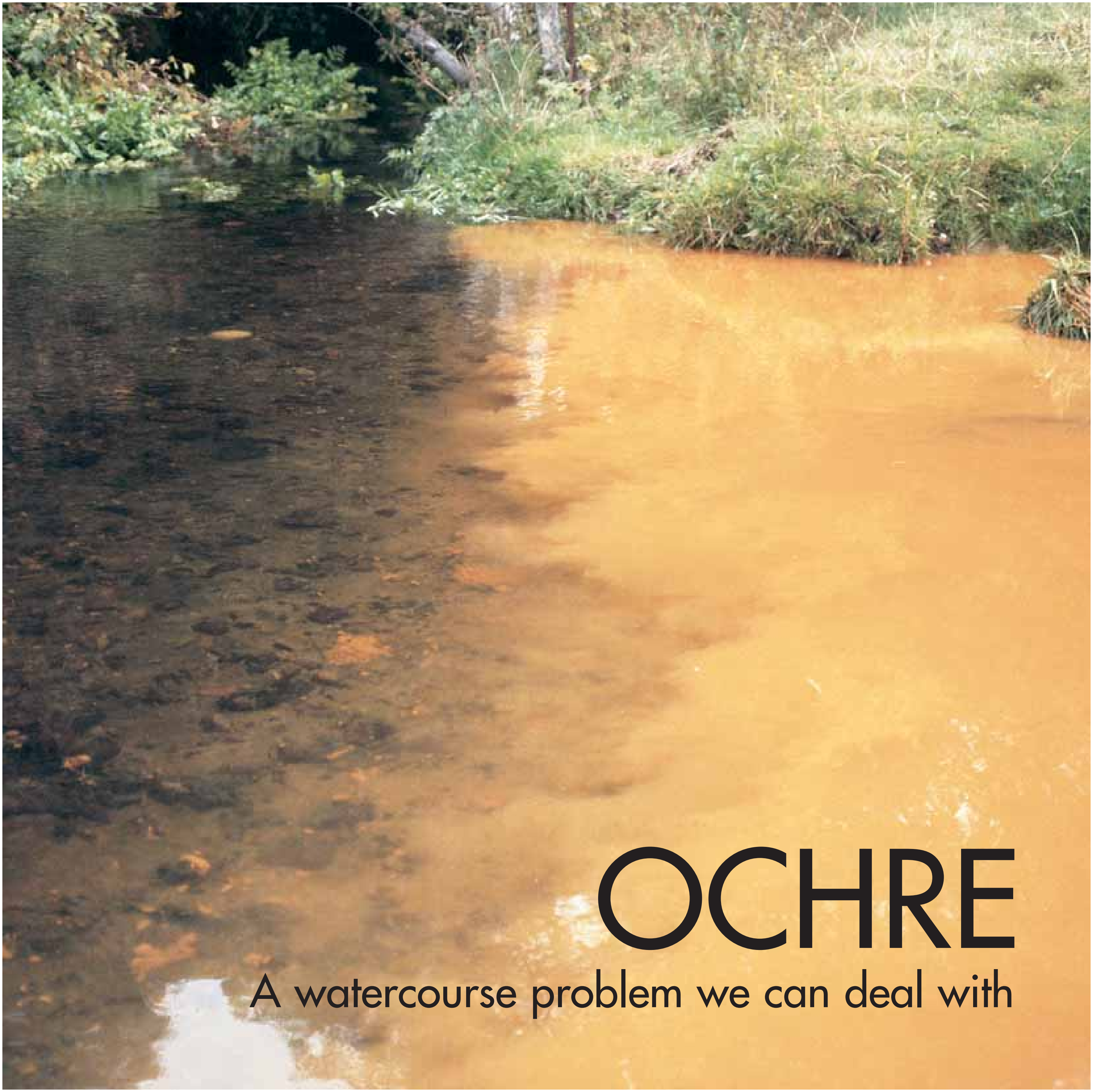

OCHRE

A watercourse problem we can deal with

Contents

Title: Ochre. A watercourse problem we can deal with

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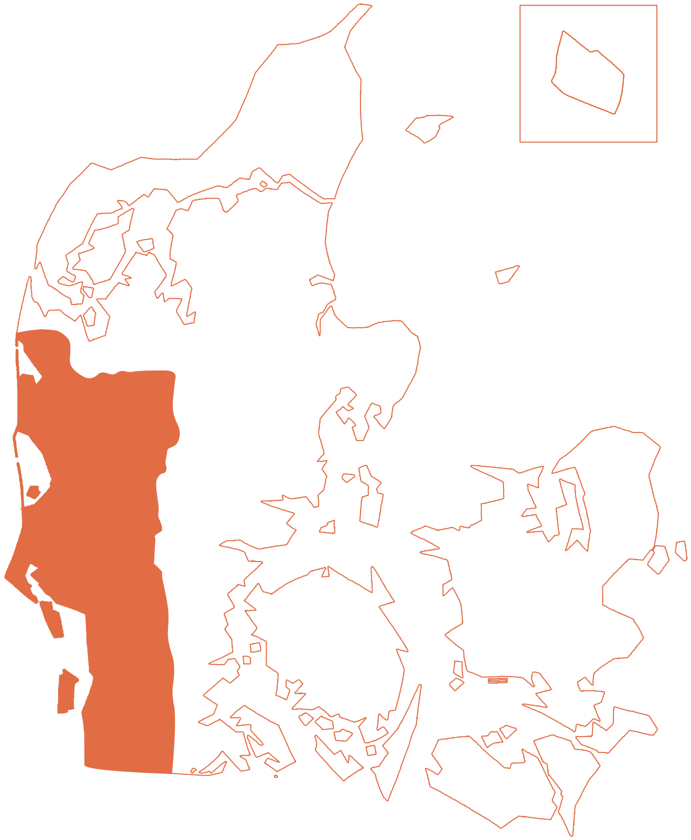
Introduction

Ochre poses an environmental problem in many watercourses in western and southern Jutland (the mainland part of Denmark). The red ochre makes the water turbid in streams and brooks. It covers the bed and coats the plants. Ochre pollution is more than just red ochre, though. It starts with acidic water and invisible, toxic iron that washes out into the watercourses. Neither fish nor macroinvertebrates can live in such water.

If we are to ensure good-quality watercourses in Denmark it is not sufficient just to treat our wastewater. Many other problems have to be dealt with, not least ochre pollution in those regions of the country where it poses a problem.

Considerable efforts have been made to reduce ochre pollution over the past 15 years, but there is still a long way to go. We can combat the symptoms by treating the water and we can solve the problem by re-establishing the wet meadows, which started to leak iron when they were drained.

Ochre pollution is largely something for which we ourselves are responsible. It arises when we change the conditions in the upper soil layers in bogs and meadows containing the iron and sulphur compound pyrite. But just as we were responsible for the release of ochre into the watercourses, we also have the power to stop it.

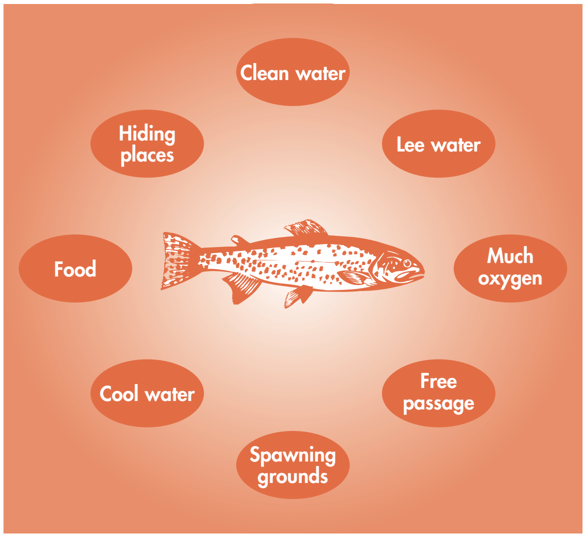


The problem is particularly great in those areas where there is insufficient limestone in the soil to neutralize acidic water. In Ribe County alone, half of the watercourses that should naturally contain a rich fish and macroinvertebrate fauna are affected by ochre. Of these, moreover, half are so polluted by iron and ochre that neither fish nor macroinvertebrates can live there. The situation is not much different in Ringkjøbing County and in the westbound watercourses in Sønderjylland County.

The path to good watercourses

One of the things that characterizes a good watercourse is the presence of trout. They are very choosy and will only inhabit watercourses in which conditions are good. One can say that the presence of trout is a measure of how clean and healthy a watercourse is.

Watercourses differ, and these differences need to be taken into consideration when assessing what environmental measures to implement. Some of the watercourses used to be good trout waters, and can become that again. Examples are streams and brooks in areas with sufficient slope to ensure a good current. Other watercourses are only drainage channels lacking in the natural conditions suitable for supporting trout. Thus even if the ochre pollution ceases, they can never comprise a suitable habitat for trout. This does not mean that it is pointless to remove the ochre from them, though, as doing so could benefit or be necessary for the restoration of good conditions in the stream or brook into which they flow.



Many requirements have to be met before trout can survive in the watercourses.

The County Councils set quality objectives for watercourses in their Regional Plans and regularly control whether they are met. The quality objectives can range from a watercourse where breeding trout should be present, to a watercourse that just has to serve as a drainage channel.

Watercourses designated as trout waters in the Regional Plan may only contain very little dissolved iron as it is extremely toxic, especially for trout eggs and fry. Ochre removal alone will not bring back the trout, however. The water has to be free of wastewater pollution too. The watercourse has to contain gravel beds where the trout can lay their eggs, and it has to contain weed beds where the trout can hide. Watercourse restoration and gentle weed clearance are thus necessary steps along the path to good watercourses.

The quality objective for many of our watercourses is that trout should be able to breed in them again.

What is ochre?

The red ochre that we see in streams and brooks derives from pyrite in the soil. Pyrite is an iron and sulphur compound that can lie unchanged in the soil for thousands of years if oxygen is excluded, for example in a wet meadow.

If oxygen reaches the pyrite, however, the sulphur and iron separate. This happens when the water table is lowered, for example when a watercourse is deepened and the meadow drained. The sulphur washes out into the watercourse as diluted sulphuric acid, and the iron follows in a form called ferrous iron. The latter is toxic and invisible when dissolved in water. In the remainder of this booklet it is just referred to as »dissolved iron«.

The iron remains dissolved as long as the water is acidic. This is one of the reasons why ochre pollution is worst in those parts of western Jutland that were not covered by ice during the last glacial period. In these areas, the soil contains little of the limestone that can neutralize the acidic water.

When the acidic water is neutralized and diluted on its journey through the meadow soil and the watercourse, things happen to the toxic, dissolved iron. It binds with oxygen dissolved in the water and turns into red ochre. In the transition between the two states the water becomes turbid and something resembling a thin oil film can appear on the surface of the water. The red ochre is not toxic, but can cause harm in other ways.

The water looks clean and clear, but it can be acidic and contain toxic iron.

This knowledge is useful when we want to combat ochre pollution. We can stop ochre pollution completely by once again preventing oxygen from reaching the pyrite, for examble by keeping the soil above the pyrite wet. This immobilizes the iron.

Alternatively, we can make do with treating the symptoms. The iron can be oxidized in ochre treatment plants comprised of ponds full of plants.

Here the invisible iron has become oxidized to red ochre.

Why is ochre harmful?

The dissolved iron and the acidic water are toxic for both macroinvertebrates and for fish. The more acidic the water, the more hazardous the iron. In very acidic water, dissolved aluminium can also wash out. This is even more toxic than iron.

The colder the water, the less well able are the small trout to tolerate the iron and the acidic water. This is an unfortunate coincidence because the ochre content of the watercourses is highest in the winter. In those watercourses in which trout and macroinvertebrates should be present the concentration of dissolved iron may not exceed certain limit values. Many macroinvertebrates and trout eggs and fry cannot survive if the concentration of dissolved iron exceeds 0.5–1 milligram per litre, which is a very low level. Large trout can tolerate slightly more.

Dissolved iron can be oxidized on the fish’s gills. It then deposits on the gills as a thick layer of ochre that the oxygen is unable to penetrate. The fish die of »ochre suffocation«. The same can happen to the macroinvertebrates, which can become coated with ochre.

The red ochre is not toxic, but can nevertheless destroy habitat conditions for animals and plants. Some aquatic plants do tolerate ochre, a fact that is exploited in ochre treatment plants, where such vegetation is used to clean the water. The majority of aquatic plants and the small algae that the macroinvertebrates live off do not thrive in ochre-coloured water, among other reasons because they receive insufficient light. The unclear water can also prevent the fish from seeing their prey.

Ochre can prevent the trout from reproducing. The latter lay their eggs in the late autumn deep down in the watercourse gravel. Here the eggs are “incubated” during the winter, and the small trout emerge in the spring.

The eggs are in the watercourse at exactly the time when the oxygen content of the water is highest. In order for the eggs to survive, fresh oxygenated water has to continually seep down to them. The ochre seals off the fine pores in the gravel that the water has to run through. As a consequence, the eggs die.

Trout eggs are destroyed by ochre.

Where does ochre come from?

When planning to combat ochre pollution it is important to find out where the iron and the ochre come from, and how much comes from the various sources. Only then can one draw up an action plan for combating the ochre pollution in a watercourse or a river system.

Among other sources, iron and ochre come from fields where the water table has been lowered by deepening the watercourses. They can wash out into the watercourses from point sources, i.e. drains and ditches. Or they can seep out directly from the field, evenly distributed along the watercourse. This is called a diffuse source, and is often seen on outwash plains, etc.

Iron and ochre can also wash out from old lignite deposits. Here the pyrite became oxidized when the lignite was mined.

In the drained fields most of the pyrite becomes oxidized during the dry season, but the acidic water and the dissolved iron are not washed out into the watercourse until the wet season. Ochre pollution in the watercourses is therefore greatest in the winter, when most water flows out from the fields.

The low temperatures are another reason why ochre pollution is greatest in the winter. Dissolved iron oxidizes more slowly in the cold water, and the toxic iron can therefore travel further down the watercourse in winter than in summer.

The ochre pollution will gradually diminish as the pyrite becomes exhausted. This can take many years, though, depending on how much pyrite is present. The very acidic water stops first, often after 25–50 years, while the iron can continue for a longer time.

The summer period can also entail special ochre problems. When weeds are cleared in watercourses where a lot of ochre is deposited between the plants, the ochre becomes resuspended in the water and can flow downstream through the watercourse like a wave of pollution.

Large amounts of ochre can also flow out into the watercourses when the field drains are flushed. The law therefore requires that all flushing water containing ochre be spread on the field so that it does not end up in the watercourse. Alternatively, it has to be collected in a gully emptier and spread on a safe place. Both the landowner and the contractor who cleans the field drains are responsible for ensuring that it does not end up in the watercourse.

Drained meadows and bogs are the major sources of ochre pollution.

This is what a formerly ochre-polluted stream can come to look like.

The Ochre Act

The Ochre Act, which regulates the prevention and alleviation of ochre pollution, was adopted in 1985. The Act also encompasses possibilities for financial support to the extent that funds for this purpose are allocated in the Government Budget. These ochre funds are largely used to alleviate and prevent old ochre damage to watercourses, both from former lignite deposits and from drained meadows and bogs.

The Ochre Act also stipulates that farmers with land located in areas at risk of ochre pollution may not begin to drain, redrain or dig ditches without first having sought and been granted permission from the County. The County has to assess whether the drainage will increase the content of toxic, dissolved iron in the watercourse so much as to deteriorate habitat conditions for the fauna. The pyrite content of the soil has to be measured, and these costs have to be born by the landowner.

If the County determines that the conditions in the watercourse where the drainage water will end up will not be affected significantly, the farmer will be granted permission to drain. If the County determines that drainage will cause ochre problems, several possibilities are open.

The County can recommend the Danish Forest and Nature Agency to approve the drainage on condition that an ochre treatment plant be established. It is possible to obtain financial support for this within the appropriation set aside for combating ochre in the Government Budget for the year. When the amount of financial support is calculated, the increase in property value resulting from the drainage is taken into account. The obligation to operate and maintain the ochre treatment plant has to be recorded in the Land Registry entry for the property.

If the area to be drained is covered with permanent grass and has not regularly been cultivated with other crops, there is no financial support to obtain. The farmer has to pay all the costs himself.

If the County determines that treatment will be inadequate to safeguard a particularly valuable watercourse, the County can recommend to the Danish Forest and Nature Agency that the drainage application be denied. The County can also reject an application to redrain an area that has previously been drained.

Since financial support for drainage ceased in 1990, drainage or redrainage of meadows and bogs has become less economically viable.

How is ochre combated?

There are two different ways of combating ochre pollution. We can prevent it, or we can deal with the consequences. This is like with disease. It can be cured, or it can be kept under control with drugs that treat the symptoms, but do not eliminate the cause.

The most effective way to combat ochre pollution is to prevent oxidation of the pyrite. It needs to be sealed inside the soil again so that the oxygen cannot reach it. This solves the ochre problem at the source, at the "root of the evil". In practice this is done by raising the water table such that the drained, pyrite-rich meadows become waterlogged again. This can be a realistic solution in the case of areas that are of little value for cultivation. However, it can be expensive or perhaps unrealistic if it encompasses large areas of cultivated land.

Another way to combat ochre pollution is to remove the iron by treating the water in an ochre pond. This is the cheapest solution in the short term, but one that rarely solves all the problems. The process is long-term, the pond has to be looked after, and it has to be emptied when it becomes full of ochre. The results are rapid, however, and the method gives a lot of environmental benefit for the investment.

Raising the water table

Ochre ponds are generally inappropriate in cases where the iron-rich water seeps out diffusely into regulated watercourses on outwash plains. Here the best method is to raise the water table. If compensation has to be paid for the wetter fields, though,

By raising the water table to the natural level, ochre pollution can be stopped. Here the bed of the brook is being raised with gravel.

this can be expensive. In order to be effective the project often has to encompass a large proportion of the river system, including many small tributaries.

The water table in pyrite-rich, drained meadows can be raised in several ways.

An obvious solution is to raise the water table in the watercourse by limiting or completely ceasing weed clearance in the watercourse. This slows down the rate at which the water is led away, thereby raising the water table. Ceasing weed clearance is the simplest method as there are no construction costs. Moreover, weed clearance costs are saved. The first step is to check whether the current level of weed clearance is in line with the watercourse regulations. Many watercourses are broader and deeper than specified in the regulations, and in some cases more weed clearance is performed than is permitted.

A good and cheap way to raise the water table is to cease weed clearance. This also provides good habitats for fish and macroinvertebrates.

Another solution is to eliminate drains and ditches so that the water flows out into the watercourse more slowly. This can advantageously be combined with cessation or limitation of weed clearance.

The water table can also be raised by remeandering a channelized watercourse. This makes the watercourse longer, reduces the slope and raises the bed of the watercourse relative to the surrounding landscape. This is the opposite of what happened when the watercourse was channelized. The bed can also be raised by laying out stone and gravel riffles.

In some lignite deposits the water table has been raised by building dams across the outlets. This covers the pyrite-rich soil layers that eventually become anoxic so the iron cannot be separated from the sulphur.

Ochre ponds

Where the iron derives from point sources such as lignite deposits, a drain, a ditch or a small brook or stream, one can construct an ochre treatment plant consisting of one or more small ponds through which the water passes. Here the iron is oxidized, and the ochre precipitates out.

If the water is acidic, i.e. the pH is less than 5, and the dissolved iron content exceeds approximately 15 milligram per litre, it is necessary to treat the water with hydrated limestone before it enters the pond. This neutralizes the acidic water so that the dissolved iron can be oxidized.

If the water contains both sedimented ochre and dissolved iron, two types of basin should be constructed in the pond – one with a depth of 1–2 metres and one that is more shallow. One can also make two separate ponds. The ochre in the water sediments out in the deep pond, and the dissolved iron is oxidized in the shallow pond.

An ochre pond has to be at least half a metre deep, preferably more if the water is clear enough to let light reach the plants. If it is lower it fills up too quickly with ochre sludge. The pond has to be large enough to enable the water to remain in it for at least eight hours, including during the winter when watercourse flow is high.

In order that the dissolved iron can be oxidized the pond needs to contain many aquatic plants. These have to be able to tolerate ochre, and they have to have a large surface area, i.e. many leaves. When the iron-rich water comes into contact with the aquatic plants, the iron is oxidized to ochre. Here, very close to the plants, oxygen is present, and the acidic water is neutralized. In addition, the plants filter the precipitated ochre out of the water so that it is not flushed out with the flow of water. Plants have to be present throughout the pond, and it is very important that the water is evenly distributed and does not take a shortcut through current channels between the plants. The ochre pond can also be followed by a deeper outflow basin where ochre formed in the pond is deposited.

In ochre ponds the dissolved iron is oxidized on plants, and the ochre precipitates out.

In addition, it is valuable to introduce gentle weed clearance or to completely cease weed clearance in the watercourse downstream of the ochre pond. This allows the water to be cleaned further since dissolved iron will be oxidized on the surface of the plants.

Conditions in the watercourse upstream of the ochre pond are also of importance. The greater the oxygen content of the water, the more rapidly the dissolved iron is oxidized. The oxygen content of the water can be raised by letting the water bubble over stone and gravel riffles.

Shrub vegetation should be planted on the western bank of the pond in order to provide shelter so that

The ochre remains in the pond, ready to be excavated.

the wind does not cause too much resuspension of the ochre. It also provides shelter for birds and game. The tree and shrub vegetation must not be so dense as to prevent the plants in the pond from receiving sufficient light, however.

The pond has to be cleaned out before it becomes full up with ochre sludge. This normally has to be done every five years. It is therefore important that right of access to the lake be recorded in the Land Registry entry for the property. As ochre sludge contains a lot of water, the treatment plant has to include a plot where the sludge can be dewatered and stored before it is taken away. The final deposition site depends on the heavy metals content of the sludge.

In order to minimize the work of digging the pond it can be built on a particularly low-lying site near the watercourse. One can also investigate the possibility of damming the watercourse in order to raise the water level slightly. This could be done downstream of a weir for example, or if the watercourse bed is actually lower than specified in the watercourse regulations.

Winter ponds

Many meadows alongside watercourses are used for grazing in the summer half-year and hence have to be dry at the time. In the winter, however, when the cattle are not present, the meadow can help remove ochre if it is flooded by the stream. In such "winter ponds" the dissolved iron is oxidized and the ochre is left deposited on the meadow when the winter pond disappears in the spring.

A winter pond can be constructed by damming the stream, making it smaller or remeandering it so that the water flows away more slowly. Winter ponds can be combined with ordinary ochre ponds in order to take the pressure off the latter in the winter time, when the ochre level in the water is highest.

Winter ponds are a step along the path to solving the ochre problem in nature's own way. The winter ponds turn the meadows back into the natural ochre treatment plants that they were for thousands of years. Originally, streams flooded their banks every winter, depositing the sand, soil and nutrients that created the meadows and kept them fertile. Ochre was also deposited on the meadows. This stopped when we regulated the watercourses. Winter ponds are an ancient natural phenomenon that we now exploit again.

In the summer, cows graze on the meadow.

In the winter, the meadow serves as an ochre pond.

Are the measures effective?

Even though raising the water table is the most effective way of combating ochre pollution, it does not always result in a rapid decrease in the discharge of ochre. Dissolved iron and acidic water that have already been released from the pyrite will continue to flow into the watercourse for some time, but no further dissolved iron will be released.

Ochre ponds can remove up to 95% of the toxic, dissolved iron and 80% of the total amount of iron, i.e. including the ochre.

These high percentages do not apply in the coldest months, however. Among other reasons this is due to the low temperatures, which slow down the oxidation of the dissolved iron. At the same time, the vegetation dies back, thereby reducing the surface area on which the dissolved iron can be oxidized. In addition, the residence time in the ochre ponds is shorter because much water flows through them.

When a measure has been implemented to reduce ochre pollution, irrespective of whether the water

This is how clean the water can be when it leaves an ochre pond.

Freshwater limpets return when the ochre has gone.

table has been raised or a treatment plant has been established, it is important to verify that the efforts are worthwhile.

The aim after all is that the watercourse should become a better habitat for fish and macroinvertebrates. It is therefore important to investigate the watercourse thoroughly before and after steps to remove the ochre are initiated. Only a few insects can survive in ochre-polluted watercourses, and an improvement will be reflected in the presence of a greater variety of macroinvertebrates following ochre removal. The best indicator that good conditions have been re-established is the return of trout able to produce viable fry.

The biological observations can be supplemented with chemical analyses. While the biological samples reflect conditions over a long, preceding span of time, however, the chemical samples only provide a snapshot. With ochre ponds in particular, it is important to measure the content of both dissolved iron and the total iron content, i.e. including the oxidized iron, upstream and downstream of the pond, and this must be done several times a year. If the water is acidic, the pH should also be measured. This is particularly important in places where limestone is added as it enables the limestone requirement to be determined. In the first few years the treatment efficiency can be low because the vegetation in the ochre pond is not fully developed.

How to get started

Before carrying out an ochre project, many factors have to be taken into consideration.

An ochre project costs money. Careful consideration therefore needs to be given to the benefit relative to the efforts. It is necessary to consider and determine how the watercourse will benefit from the project, and whether it can reasonably be expected that a good population of fish and macroinvertebrates will develop if the project is implemented. Priority should be given to projects that will benefit the environment in watercourses with a high quality objective rather than those with a low quality objective. It can still be appropriate to remove ochre from watercourses with a low quality objective such as ditches, however, if this will benefit watercourses with a high quality objective located further downstream in the river system.

Much information has to be collected about the extent of the ochre pollution, about the watercourse and its surroundings, about land ownership, etc. One has to choose how best to solve the ochre problem. If one chooses to raise the water table, it is necessary to determine how great an area this will encompass, and what methods can be used. If an ochre pond is to be established, it is necessary to determine if limestone needs to be added to the water, whether a sedimentation basin is needed, how large the pond should be, and where it could best be located.

The areas where ochre projects are to be implemented are usually privately owned. It is therefore necessary to involve the landowners in the plans very early in the process. Without their willing acceptance it is unlikely that the projects can be carried out. They should be included as early as in the idea phase so that they can make suggestions as to how the project can be implemented in practice. One can discuss whether it is possible to establish a winter pond, whether the water table can be raised without damaging crops, or whether depressions exist where an ochre pond could be established easily and cheaply. Perhaps this could be combined with special wishes regarding game or nature management.

The financial aspects also have to be assessed. Financial support can be applied for at the Danish Forest and Nature Agency pursuant to the Ochre Act. Other possibilities can be the fishing licence proceeds, which are administered by the Danish Veterinary and Foods Administration, and the nature management funds, which are administered by the Counties. One should also investigate whether a project can be combined with agri-environmental measures and possibly also with the wet meadow scheme under the Action Plan on the Aquatic Environment.

Once agreements have been reached with the landowners, the investigations have been completed, and the financial aspects assessed, a draft project can be drawn up that has to undergo a four-week public hearing. This is because permission and any necessary exemptions have to be applied for before an ochre project can be carried out.

It is the watercourse authority that decides whether an ochre project may be implemented. This is because legally speaking, ochre projects are watercourse regulation projects and the Watercourse Act requires that prior permission must be granted by the watercourse authority. In the case of county watercourses, i.e. the large watercourses, the County is the watercourse authority. In the case of municipal and private watercourses, the Municipality is the watercourse authority.

Nearly all ochre projects are located in wetlands encompassed by Article 3 of the Protection of Nature Act. Among other things, this states that watercourses encompassed by the Act may not be altered without the permission of the County Council. Neither is it permitted to alter meadows, bogs and the suchlike if they are larger than 2,500 m^2.

Only once any objections and complaints have been dealt with, and the necessary deadlines have been met may work on the actual project begin. Guidance on this (in Danish) is also available at www.okker.dk.

The ochre level continues to fall in the remeandered river Savstrup.
The mayfly has returned – a tasty prey for the waiting trout.

Ochre pollutes many watercourses in western and southern Jutland. It comes from drained meadows and from lignite deposits.

In order to restore our watercourses to such good condition that we can catch trout in them again we need to combat ochre pollution. This is just as necessary as wastewater treatment and gentle weed clearance.

Considerable efforts have been made to reduce ochre pollution over the past 15 years, but there is still a long way to go.

This booklet describes the problems posed by ochre and the possibilities to solve them. Just as we were responsible for the ochre pollution, we also have the power to combat it. This does not require large technical facilities such as those needed for wastewater treatment. What is needed is to re-establish certain natural conditions so that nature can keep the ochre under control itself.

The booklet provides a collection of experiences. It is directed at municipal authorities, because many ochre-polluted watercourses are under their jurisdiction, and at farmers, who want to see into the possibilities to contribute to better watercourses. It is also directed at anglers and others who are interested in ensuring good quality watercourses.

For more information see www.okker.dk.