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27 WILLOW COPPICE PLANTATIONS AS WASTEWATER TREATMENT SYSTEMS

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ABSTRACT

Short rotation willow coppice (*Salix*) can be used as vegetation filter to treat industrial and municipal wastewater. In May 1998 a EU-FAIR project, "Biomass short rotation willow coppice fertilized with nutrient from municipal wastewater (BWCW)" was started to investigate the consequences to establish willow plantations to treat wastewater in some European countries with varying climatic conditions. The aims of this research project were to evaluate the positive effects of irrigation of willow-to-energy plantations with wastewater, but also to find the negative consequences and to develop strategies to deal with them. The project comprises comparable pilot plantations located in four different climatic regions in the four European countries: France, Greece, Unite Kingdom and Sweden. In this paper the experiences from this EU research project BWCW, which will be finished off in 2002, are briefly described.

KEYWORDS

Willow coppice, Salix, wastewater, vegetation filters, EU project.

INTRODUCTION

Today willow coppice is an established agricultural crop for two main reasons. There is an increasing need a) for bio-energy to replace fossil fuel (1) as well as a need b) for alternative crops in agriculture. Wood chip from willow coppice are used today as a fuel for district heating in Sweden, producing about 0,2 TWh of heat annually. Willow coppice is planted on about 16.000 hectare in the country as an alternative crop on "set aside" land and from this area about 3.000 hectares are harvested annually for bio-energy. If willow biomass plantations are located adjacent to some water treatment station these plantations are possible to use for purification of wastewater, at the same time.
There is a big need for purification systems for wastewater all over the world. More strict regulations to avoid pollutions of soil, rivers and air have put a stronger pressure on urban societies to improve their treatment systems and also to extend the systems to sources of wastewater, which not have been treated before. Today, most new constructions of wastewater treatment plants are built according to conventional techniques (concrete, chemicals and computers), often to very high costs. There are many good reasons to change to more environmentally friendly and cheaper techniques.

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Natural purification techniques using vegetation filters have been shown to work very efficiently (2), in many cases better that conventional treatment systems, but also at a fairly low costs (3). The focus today on building large centralised, high technological purification systems will stand in the way of development towards more natural systems. It is time now to break this trend and to try some other alternatives.
A number of municipalities in Sweden have established willow/wastewater treatment systems already, in a smaller scale (Svalöv, Åstorp, Bromölla, Enköping and Hedemora). The experiences from these treatment systems are positive (2). There are a number of additional advantages to treat the water by vegetation filters, except the high efficiency and the low costs. Municipal wastewater contains small amounts of heavy metals, which can be absorbed by the plant and separated from the ashes when the wood chips from the harvested plants are incinerated (4). Wastewater also contains small amounts of organic substances, like antibiotics and others, which can have a direceffect on micro-organisms in aquatic environment. When wastewater is treated in vegetation filters such substances can be converted by biological processes in the soil to less harmful ones before they later on reach streams, rivers and lakes.
The system to treat wastewater in willow plantations is rather new and all implications of the system are not fully investigated. Experiences from already established willow/wastewater plantations and the knowledges coming out from the BWCW project (5) will give a better base for taking decisions for investments in such systems.

THE BWCW PROJECT

The BWCW project concerns an integrated investigation to provide a EU-wide scientific basis for growing willow coppice for bio-energy production using municipal wastewater rich in plant nutrient (substituting commercial fertilisers). This will give a simultaneous sanitarily safe, economically feasible and environmentally acceptable technique for disposal of wastewater into willow plantations leading to elimination of rivers, underground, and coastal water pollution. The specific objectives for the project are:

- To study growth and biomass productivity of short rotation willow coppice for energy use grown under irrigation with municipal wastewater.
- To determine the most suitable irrigation rates of wastewater aiming at environmentally safe wastewater disposal and maximal biomass production.
- To monitor leaching of minerals to deeper soil layers and to assess which irrigation rates are suitable to eliminate underground water pollution.
- To follow the uptake of certain minerals into the various plant components as well as their retention in the various soil layers.
- To investigate the effect of the willow/wastewater irrigation system on landscape, sanitary implications, pests and diseases.
- And finally, to evaluate the economy of the system in terms of purification of wastewater and production of biomass on farmland.

Experimental sites
Field trials have been established in four European countries, from south to north. The fields are located in the vicinity of municipal wastewater treatment plants and in one case (in France) close to a food industry, producing chicory sugars. In Sweden the

experimental field is located at Romakloster, on isle Gotland, in France at Orchies close to Lille, in Northern Ireland at Londonderry and in Greece at Larissa, in the central part of the country. Each trial covers about 5 hectare. Studies are made for biomass productivity and reallocation of nutrient components with three irrigation rates of wastewater. These trials also include irrigation with clean water for comparison and in one trial (in Sweden) humane urine, delivered from an adjacent school.

Measurements
During the course of the project, growth measurements are made and samples are taken of the chemical compositions in wastewater, clean water, biomass, soil, groundwater and human urine. The effects of the various treatments on vegetation, soil and underground waters are determined. The economics of growing willow coppice irrigated with wastewater will be evaluated, including both production and value-added-chain apportions. In addition, the effects of institutional and social-economical factors will be analysed. The consequences of the wastewater treatment on the surroundings of the municipal waste treatment plant will be evaluated. Studies of certain pathogens and the wildlife within and around the plantation are made each year.

Plant material
The SW-variety Jorr are used in all trials, because it is rather tolerant to hot and dry conditions, but also well adapted for more humid conditions. Also irrigated with wastewater the plants will be stressed by the high evapo-transpiration rate in arid regions. The climatic conditions are quite different in Greece compared to Northern Ireland. The temperature at Larissa in Greece some days has risen up to about 40 C degrees. In such conditions the leaves on Jorr are curled and discolored. In spite of that the biomass production in Larissa is not less than on the other sites, between 7-13 tonne dry matter per hectare per year.

Irrigation
The schedule for irrigation is different for each site depending on the local climatic conditions. The PE (potential evapo-transpiration) is calculated for each site from the local climate data and the supply of water is given according to that. The supply of water to the experimental plots is made by drip irrigation in Sweden, France and Greece (under soil surface) and by sprinklers in Northern Ireland.

Biomass
Biomass measurements are made each season. There are more clear differences in biomass production during the second year between the different treatments than during the first year. There will be made a third, final, measurement of the biomass this winter. Highest biomass growth on all sites are observed in 2 x PE and 3 x PE of wastewater. The biomass production seems very much been related to the addition of water. How much of the effect is related to the addition of water or to the “extra” supply of nutrient from the wastewater will be analyzed.
The yield production has very soon come up to yield levels above the levels in commercial plantations without irrigations. The effect of water and nutrients from the wastewater is also expected to raise the biomass production in the plantations to considerable higher levels compared to plantations without irrigation. This is one of the

positive effects of the technique. The extra bonus of higher production will also influence the economy of willow/wastewater plantations.

Chemical analyses

The main part of the chemical analyses of the plant tissues will be taken at the end of this year, after harvest of the plantations. Initial analyses of the soil texture and chemical composition have been made from all four experimental sites.

The level of the groundwater table is very much dependent on the local climatic conditions. The groundwater table was in Greece in Dec 2000 on about 7,0 m, which made it impossible to collect soil water for analyses during that period. The groundwater table in Sweden was as lowest on 3,0 m, in summertime 1999. The groundwater levels varies, however, depending on season and on the supply of water from the irrigation. In Northern Ireland and in France the groundwater was varying between 2,0 and 0,5 m.

Chemical analyses of the groundwater have regularly been made from all sites. The final conclusions about the distribution of nutrients and other chemical substances within the system will be analyzed at the end of the project period, when data from soil, biomass, groundwater and applied wastewater will be modeled together. To study the environmental aspects and leaching into the soil water Cl^- is expected to be an indicator substance.

Wastewater and clean water

The conditions of wastewaters vary a lot between the sites. In Greece and Northern Ireland the effluent comes directly from a treatment station and has a relatively high content of N, about 35 mg/l in Greece and about 20 mg/l in Northern Ireland. In Sweden, where open ponds are used for pre-treatment of the wastewater, the content of N has been reduced a lot before it is used for irrigation in the trial. The level of N is as low as about 3,8 mg/l. The level of N in the wastewater is not much higher than in the clean water (1,7 mg/l) at Romakloster, taken from the river/stream through the village. The clean water N in Northern Ireland and Greece is at about 2,5 mg/l.

Sanitary aspects

The results from investigations made in three willow/wastewater plantations in southern Sweden (tracer-studies, feacal dropping studies and site specific assessment from two sites in southern Sweden) have been followed up during year 2000 by study of samples from Sweden, Northern Ireland and Greece. During 2001 these investigations have been followed up with complementary samples of wastewater, groundwater and feacal stools from the different areas. The aim is to make a comparative risk validation between the different sites. This will further lead to generalized recommendations in relation to sanitary actions and risks for pathogen transmission.

Biological aspects.
Within the project insects, plant diseases and weed have been observed and recorded. The effect of treatments on pest composition and populations are assessed. Any variation of pest occurrence between the various experimental fields is studied along with the climatic conditions of each region.

Information material and demonstration sites
Information will be available from the BWCW project how to establish willow plantations as a filter to treat wastewater and to produce bio-energy at the same time. The project will make the environmental risks and possibilities in this technique more clear. A manual "How to establish and tend willow plantations as vegetation filters for municipal wastewater" will be produced and freely distributed.

The BWCW plantation at Romakloster on isle Gotland in Sweden is very useful as a demonstration site for the willow/wastewater treatment system. It is easy to reach from adjacent main roads. The plantation is also located in an area where this type of treatment system of wastewater is the most natural way to go. There are plans to maintain the plantation as it is with a continued irrigation with wastewater also after the termination of the BWCW project, in June 2002.

DISCUSSION

Water, and also wastewater, has very different economical value in different countries. In dry and hot areas wastewater normally are used for irrigation also of fruit and arable crops, and it is not a problem to find users for that water. The interest to grow willow just to get rid of the water is of that reason not so big, if not willow economically can compete with other crops where wastewater can be used. Also in these cases, however, a certain type of treatment of the water is necessary to make it sanitarily and environmentally safe for use on food crops. In countries with a more humid climate the idea with treatment of wastewater is more to get rid of the water in an environmentally safe way, and to a reasonable low cost. Often the use of wastewater on agricultural crops is more restricted. Willow as a non-food crop is more acceptable to be irrigated with wastewater.
The quality of the wastewaters (industrial or municipal) are very variable. Each wastewater treatment system has to be managed separatetly, depending on the origin of the wastewater. Industrial wastewater and often more polluted by chemicals like heavy metals and other compounds not found in municipal wastewaters. On the other hand the industrial wastewater has less of pathogenes and are more easy to handle of that reason. The industrial wastewater from the chicory industry in France in the BWCW project contains large amouts of organic matter, soluble and insoluble. This has created some problems with clogging of the irrigation tubes, but it will also influence the microflora in the soil a lot (in negative or positive ways?).
The technique to irrigate wastwater has been discussed very much, of technical and sanitary reasons. Sprinklers or drip irrigations, that is the question. To avoid airosol drips and dispersion of pathogenes drip irrigation systems seems to be best, but a compleate answere to that we don't have yet. In dry and arid regions drip irrigation and

also drip irrigation below the soil surface can be prefered, to avoid to big losses of water through evaporation.

The willow material available today is not adapted for dry and hot regions. Collections of local clones from the area of Larissa in Greece have therefore been made. This material have been crossed to other higher productive clones to produce hybrids more adapted for southern region. Also material from Italy and Croatia have been collected for the same reason. Such hybrids are now in observation trial at Svalöf Weibull AB. In future wastewater/willow plantations probably better adapted plant material for southern more hot regions will be available.

To be an effective plant for treatment of wastewater a high biomass production is to prefer. Larger amounts of water can be evaporated, larger amounts of waste substances can be absorbed by the plants and larger amount of bio-energy will be produced. To that, it is important to have a plant material which is resistant to pest an diseases to avoid growth reductions and plant death in the plantations, which are assumed to be in operation in at least 25-30 years.

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