

Development of process technology for treatment of textile wastewaters

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Introduction

Considerable amounts of dyes are wasted during textile processes due to hydrolysis in dye baths and the resulting effluents thus contain high concentrations of dyes. The presence of dyes in wastewater is a problem of great environmental concern in many parts of the world. Dyes are designed to resist UV-light and chemicals and these criteria yield compounds that are not easily degraded in the environment (Nilsson *et al.*, 2005). The most common type of synthetic dyes is azo dyes and the removal of these dyes from effluents is desired, not only for aesthetic reasons, but also because they can be degraded to aromatic amines under anaerobic conditions. Some of these amines are carcinogenic and when the wastewater is released there is a risk of ground water and drinking water contamination (Bruins *et al.*, 1987; Riu *et al.*, 1997). The most common techniques for treatment of dye wastewater today are based on chemical precipitation, which leads to formation of hazardous waste containing undegraded dyes (dos Santos *et al.*, 2004). An attractive alternative could be to use biological methods since they are known to be both environmentally friendly and cheap (Nigam *et al.*, 1996).

In this project we look for a treatment option that is robust, cheap, degrades the dyes completely and allows reuse of water. The studied options are white rot fungi, bacteria and photocatalysis. White rot fungi degrade lignin using extracellular enzymes. Since the enzyme systems are non-specific, the fungi can be used to degrade persistent pollutants such as synthetic dyes (Libra *et al.*, 2002). Azo dyes can be degraded by bacteria using sequential anaerobic-aerobic treatment. Under anaerobic conditions the dye is decolourized and cleaved into aromatic amines, which can be further degraded under aerobic conditions (Sponza and Isik, 2005). The last option is photocatalysis where photodegradation of dyes is enhanced by a catalyst, in this case TiO₂ (Bizani *et al.*, 2006).

Methods and materials

Dyes

The azo dye Remazol Red RR (manufactured by DyeStar), was provided by a textile factory in Tamil Nadu, India. The chemical structure of the dye is unavailable since it is protected by patent.

Fungal treatment

The white rot fungi *Bjerkandera* sp. was grown by transferring plugs from the growing zone on a malt agar plate to an Erlenmeyer flasks containing malt extract medium. After 5 days incubation enough biomass had developed and could be used for inoculation of dye-containing samples. A dye concentration of 100 mg/l was used in all experiments.

Fungal decolourization experiments are often carried out using glucose as carbon source, but to develop a cheap process the feasibility of using agricultural waste such as straw and wood chips was investigated in batch tests under sterile conditions. The treatment was thereafter scaled up to 1.5 L continuous reactors. The process performance was also investigated under non-sterile conditions.

Bacterial treatment

The anaerobic and aerobic inoculum was collected from Källby wastewater treatment plant in Lund, Sweden. Anaerobic batch decolourization experiments were conducted for different dye concentrations (100-2000 mg/l). The headspaces of the bottles were flushed with nitrogen to obtain anaerobic conditions. The bottles were inoculated with anaerobic sludge and incubated until completely decolorized. After decolourization the content of the bottles were subjected to aerobic treatment. This was done by inoculating with activated sludge and changing the gas-tight caps to gas permissible cotton plugs.

Photocatalysis

Photocatalysis, using TiO_2 (titanium dioxide) as a catalyst, was conducted in glass tubes filled with dye solution (100 mg/l) and TiO_2 powder. The tubes were placed on a shaker and irradiated with UV lamps during 24 h. Since many textile industries are situated in warm countries the abundant sunlight could be used instead as an efficient UV source in a real wastewater treatment plant.

For large-scale applications the TiO_2 needs to be immobilized on a solid support to avoid an expensive separation step. Immobilization on glass slides using different techniques such as thermal immobilization and binding agents was evaluated. When using TiO_2 repeatedly some of the activity was lost and therefore regeneration techniques using UV-light, heat and NaOH were also evaluated.

Analytical methods

Degradation of the dye was evaluated by absorbance scanning. Decolourization can be seen as a reduction of the peak in the visible region and degradation of aromatic structures is represented by reduction of the peak in the UV region.

COD (chemical oxygen demand) is often used as an indirect measure of the amount of organic compounds in water. The COD reduction was determined for the photocatalysis, but not in the fungal and bacterial experiments since the COD contribution of the dye was too low compared with the COD contribution of the added carbon sources.

Results and discussion

Fungal treatment

In fungal batch treatment decolourization efficiency was found to be high and the fungi were also capable of decolorizing dyes when straw was used as carbon source (Fig. 1).

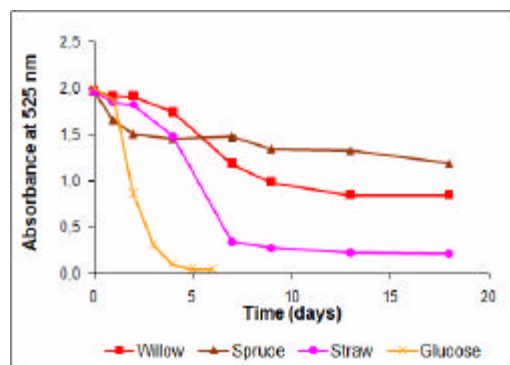


Figure 1. Decolourization of Remazol Red RR by *Bjerkandera* sp BOL 13 using various carbon sources.

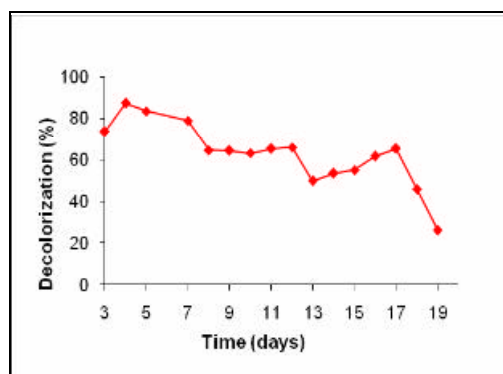


Figure 2. Decolourization of Remazol Red RR by *Bjerkandera* sp BOL 13 under non-sterile conditions in a continuous reactor.

Continuous decolourization was carried out in reactors. The efficiency was good in the beginning but the reactors were easily clogged due to fungal overgrowth and under non sterile conditions they collapsed after 19 days due to contamination (Fig. 2). These problems need to be overcome for use of this treatment technique in full scale applications.

Bacterial treatment

Bacteria are very robust and anaerobic decolourization was efficient. Figure 3 shows the complete reduction of the visible peak after anaerobic treatment. It can also be seen that the wavelength of the UV peak is shifting due to degradation into corresponding amines. However, the amine peak in the UV range was only reduced by approximately 25 % after the aerobic treatment, which indicates that the amines were not fully degraded. Further work has to be conducted to find a better aerobic culture for complete degradation of various aromatic amines.

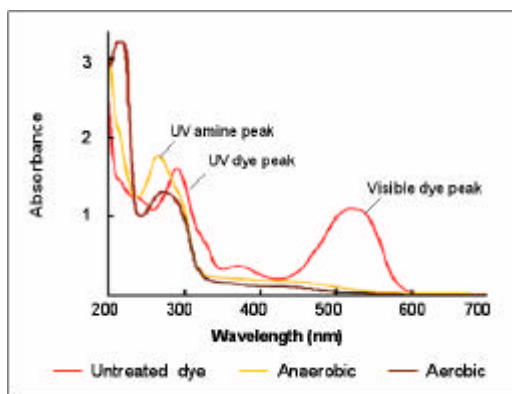


Figure 3. UV-vis scanning of Remazol Red RR before treatment, after anaerobic treatment and after aerobic treatment. The graph shows absorbance as a function of wavelength.

Photocatalysis

Using photocatalysis the dye was completely decolourized in 8 hours and complete degradation was achieved after 24 hours as can be seen by the total reduction of COD (Fig. 4). The thermal method was a good way of immobilizing TiO_2 but better ways of regenerating the catalyst has to be found.

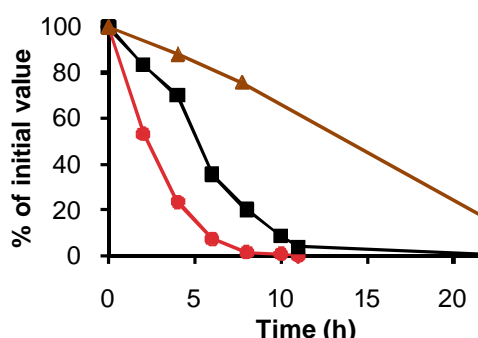


Figure 4. Photocatalytic degradation of Remazol Red RR. Evaluation of decolourization, degradation of aromatic structures and COD reduction.

Conclusions and future work

In conclusion the bacterial treatment showed promising results and seems to be more robust than the fungal treatment process. Photocatalysis could also be included to improve the biological degradability if regeneration of the catalyst is improved. Further work will be conducted to improve the methods and to develop toxicity tests to ensure that the treatment will deliver non toxic, reusable water.

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