POTENTIAL OF SULPHATE-REDUCING BACTERIA FOR DEGRADATION OF CARBON POLLUTION – APPLICATION TO HORIZONTAL SUBSURFACE FLOW SAND FILTERS

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ABSTRACT

The scientific literature highlights that sulphate-reducing bacteria need to oxidize a carbon source in order to reduce sulphates. Starting from this observation, the main objective of this project is to study if sulphate-reducing bacteria have the potential to degrade carbon pollution in horizontal subsurface flow sand filters. Two parallel horizontal sand filters have been designed. After a seeding period with wastewater coming from the wastewater treatment plant of Strasbourg, both horizontal sand filters have been fed with a synthetic influent. One of the horizontal sand filters was fed with an influent representative of a sulphate-rich carbon-polluted wastewater, in order to favour the growth of sulphate-reducing bacteria. The second one (used as a reference) was fed with an identical influent, but without sulphates. After a maturing period to allow sulphate reducing bacteria to develop, the COD reduction is about 95%, and equivalent to the one observed for the horizontal sand filter used as a reference. Though the influent of the horizontal sand filter fed with sulphates is very acid (pH ≈ 4-5), and the concentration in dissolved oxygen reach zero (anaerobic conditions), the decrease in COD is important and allows an effluent concentration inferior to 40mg/l of COD. Thus, we have settled a system that is similar to acid mine drainage (AMD), but that allows a good degradation of carbon pollution.

Key words: Biodegradation, Carbon pollution, Horizontal subsurface flow sand filters, Sulfate reducing bacteria, Sulfate reduction

INTRODUCTION

Sulphate-reducing bacteria need to oxidize a carbon source to have enough energy to reduce sulphates (Pelmont, 1993; Reddy & DeLaune, 2008). The main objective of this project is to study if sulphate-reducing bacteria have the potential to degrade carbon pollution that takes place in horizontal sand filters (HSF).

Two horizontal subsurface flow sand filters have been designed, one of them used to set up the experiment and the other one used as a reference. Tracer experiments revealed identical hydraulic behaviour within the two filters. After a seeding period with wastewater coming from the wastewater treatment plant of Strasbourg, both horizontal sand filters have been fed with a synthetic influent representative of a carbon-polluted wastewater. To run the experiment, the first horizontal sand filter was fed with a sulphate-rich carbon-polluted influent, while the other one was fed with a common carbon-polluted wastewater.

Several parameters have been continuously monitored, such as temperature, pH, Redox potential or dissolved oxygen, both inlet and outlet. Moreover, the comparison between the carbon reduction in the two horizontal sand filters (COD, BOD and TOC) has been done twice a week to have information concerning the influence of sulphate-reducing bacteria on the treatment of carbon pollution in horizontal sand filters.

METHODS

To run this experiment, two horizontal subsurface flow sand filters have been designed (cf. Figure 1). Their dimensions are 3m(length) × 0.5m(width) × 1m(depth). The HSFs of 0.8m effective height of media were filled with sand (40% porosity, d_{10} = 0.19, d_{60} = 0.7, uniformity coefficient = 3.68 and hydraulic conductivity = 4.2×10^{-4} m/s).

Figure 1 : The two horizontal sand filters

The seeding took place during 3 weeks, with wastewater coming from the wastewater treatment plant of Strasbourg. The average concentrations in the influent were 157.7± 18 mgCOD/l, 77.4±11.3 mgBOD/l and 65±4.2 mgTSS/l. The average temperature varied from 14°C to 23°C. The flow rate was 4l/h.

After the seeding period, the two horizontal sand filters were fed with similar influents, except for the presence of sulphates in HSF_A (added in ferrous sulphate form). The composition of the two influents is given in Table 1.

Tableau 1 : Composition of the two influents (loading rate: 36gCOD/m³of sand/d)

Chemicals	SF A (with sulphates)	SF B (without sulphates)
CH_3COOH	478.4mg/l	478.4mg/l
Fe_2SO_4	2.5g/l	--
$MgSO_4$	226.9mg/l	--
NH_4Cl	16mg/l	16mg/l
NaH_2PO_4	7.4mg/l	7.4mg/l
$MgCl_2$	--	54.9mg/l

To compare the treatment yields of the two horizontal sand filters, it was necessary to monitor several parameters, such as COD, BOD, TOC and sulphates.

RESULTS AND DISCUSSION

The analyses revealed that, for the HSF_A, the influent was similar to an acid mine drainage (AMD) (Neculita et al., 2007). Indeed, the average pH was about 5.0, and it was very rich in sulphates ($[SO_4^{2-}]_{inlet}$ = 1,12g/L) and in ferrous ions (($[Fe^{2+}]_{inlet}$ = 330mg/L). Nevertheless, contrary to most of the studies concerning AMD, we were able to treat carbon pollution very efficiently as shown in Figure 2 (the average treatment rates for COD are about 95% after one month of experiment).

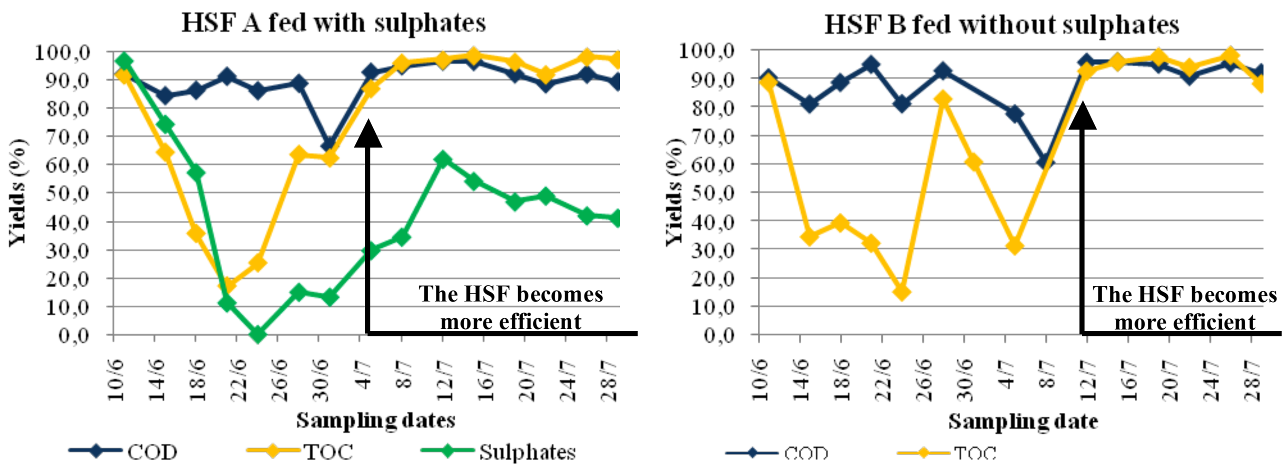

Figure 2 : Pollutants removal in horizontal subsurface flow sand filters A and B

As we can notice in Figure 2, HSF_A needs about three weeks to reach high treatment rates for COD and TOC. Concerning sulphates, the treatment rates are about 50% after one month of working. That period might correspond to the time the sulphate-reducing bacteria need to grow and to be able to degrade both sulphates and carbon pollution. After that period, the quality of the effluent becomes very high, with values below 40mg/L (cf. Figure 3).

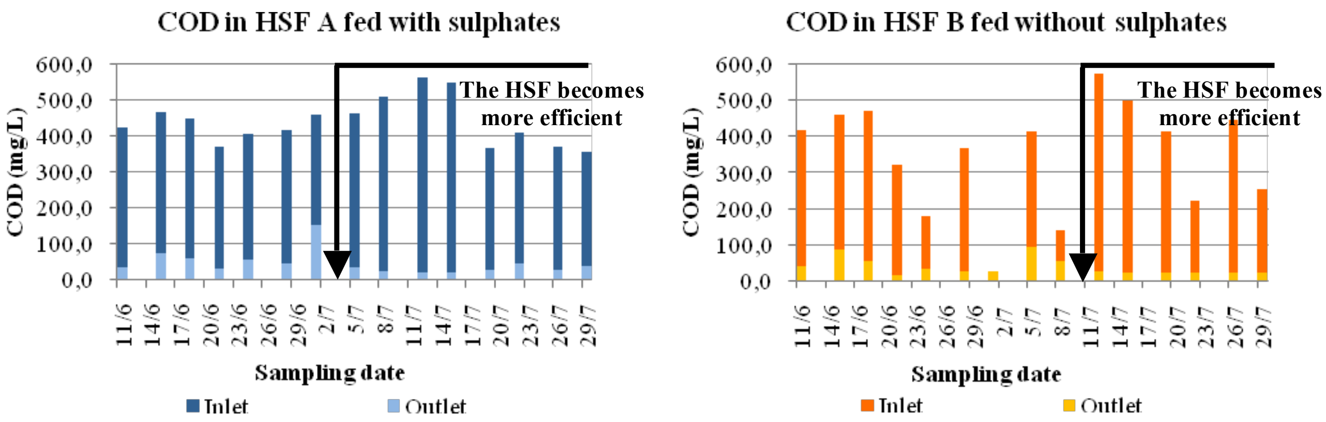

Figure 3 : COD in inlet and outlet for horizontal subsurface flow sand filters A and B

Concerning HSF_B, one month is necessary before reaching good treatment rates for both COD and TOC. We can conclude that the microbial populations that degrade carbon pollution in "usual" horizontal sand filters need more time to grow and become efficient than the microbial population present in the one fed with sulphates. For this case, the COD values at the outlet are also below 40mg/l (cf. Figure 3).

Moreover, despite the major differences between the two HSF, the treatment efficiency reached for HSF_A is similar to the one obtained for HSF_B. Thus, the system we set up offsets the unfavourable initial conditions that in general do not permit a good degradation of carbon pollution, i.e.: low pH, high concentration in sulphates and presence of heavy metals (ferrous ions in our case; cf. Figure 4 – presence of iron oxide).

Figure 4 : The two sand filters after two months of experiment

CONCLUSIONS

The study has highlighted the excellent potential of SRB for the degradation of carbon pollution within horizontal subsurface flow sand filter. Besides, although the conditions in influent containing sulphates are very unfavourable to a good degradation of carbon pollution, the system we settled compensates for that. Indeed, the quality of the effluent is very good for the two horizontal subsurface flow sand filters.

Moreover, the two systems need several weeks before becoming efficient to treat carbon pollution. The efficiency yields become as high as 95% for both horizontal subsurface flow sand filters. Further research works would focus on the different bacterial communities responsible in the treatment processes with the two HSF.

REFERENCES

Neculita C.M., Zagury G.J., Bussière B. (2007). Passive treatment of Acid Mine Drainage in bioreactors using Sulfate-Reducing Bacteria: Critical Review and Research Needs. Journal of Environment Quality, 36, 1-16

Pelmont J., (1993). Bactéries et environnement – Adaptations physiologiques. Presses Universitaires de Grenoble.

Reddy K.R., De Laune R.D., (2008). Biochemistry of Wetlands – Sciences and Applications. CRC Press. New-York, U.S.A.