Biofilm growth in a Biological plate tower, BPT, for VOC air pollution treatment

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Abstract The growth of microorganisms in biofilters and biotrickling filters always leads to the occurrence of clogging. A good efficiency of removal makes it happen faster. To solve clogging and making that kind of process easy to operate steadily for a long time, a new concept of reactor was designed and tested with air polluted with toluene and *Pseudomonas putida*. The BPT is a cascade of plates to whose surface the bacteria attaches. Water flows down and air flows upwards. The reactor shows very good hydrodynamic performance and operates continuously without problem. When the thickness of the biofilm reaches the maximum value allowable, the set of plates is simply replaced by a clean one and the biomass is dealt with outside the reactor.
Keywords BPT; biofilm; clogging; VOC; *Pseudomonas putida*

Introduction

The use of four phase (liquid, solid, gas-vapour and biological) or three phase (liquid, solid and biological) reactors always brings about several problems related to hydrodynamics. Sloughing, channelling and clogging always occur. Backwashing and/or sedimentation are to be considered. In the present work a new conception of bioreactor was tested and its performance compared with the classical biofilters and biotrickling filters (BTF).

The observation of the bacteria growth on plane surfaces (top liquid distributor, base plate, see figure 1) suggested that the use of a new conception, based on horizontal surfaces, should be tried. Therefore, a reactor was adapted to become a BPT. Basically, the BPT is a pile of parallel circular plates with a single hole on the border. The plates are placed in such a way that the holes will alternate (180^{o}) from one to the other. In this way, a cascade of liquid will go downwards, changing direction from plate to plate. The gaseous stream follows the opposite direction, upwards.

The removal of the exceeding biomass inside the reactor does not oblige the operation to be stopped, or severely shaken as it happens with BTF. Unlike biofilters whose package has to be rejected after a certain time of operation, BPT biomass is withdrawn as a water rich solid phase, the biofilm attached to the plates, and quite easy to handle.

Figure 1 Liquid distributor showing the growth of biomass on the lower surface. The same occurrence, even stronger, could be observed on the top side.

Materials and Methods

The reactor is a four module (about 28.8 dm^3 each) BPT with 20 plates in each module. Figures 2 and 3 show the global apparatus and the details of a set of plates and the shape of each plate.

Only three of the four modules are operated continuously. The fourth module is kept free and ready to replace any of the other ones that reaches saturation with biomass.

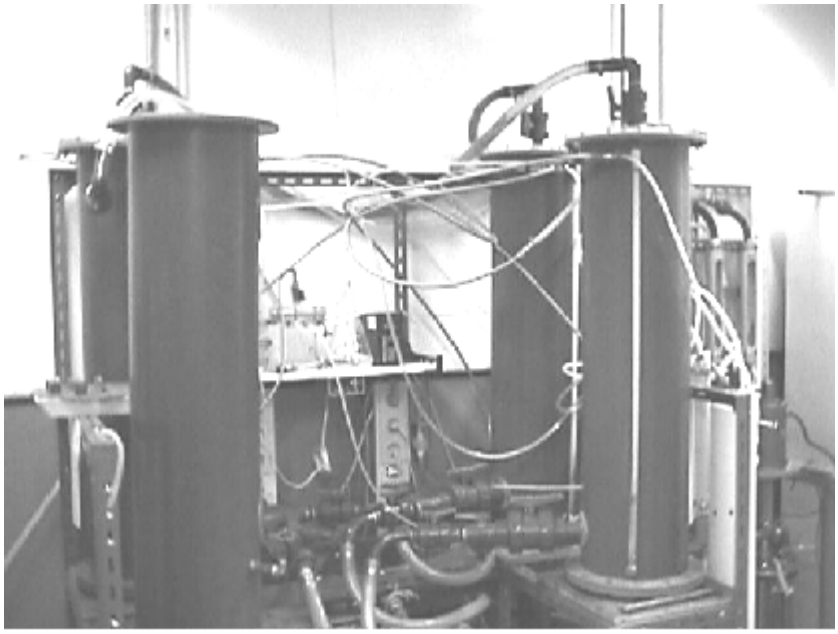

Figure 2 Photograph of the lab installation with the four modules (three in operation) and all the connections and valves.

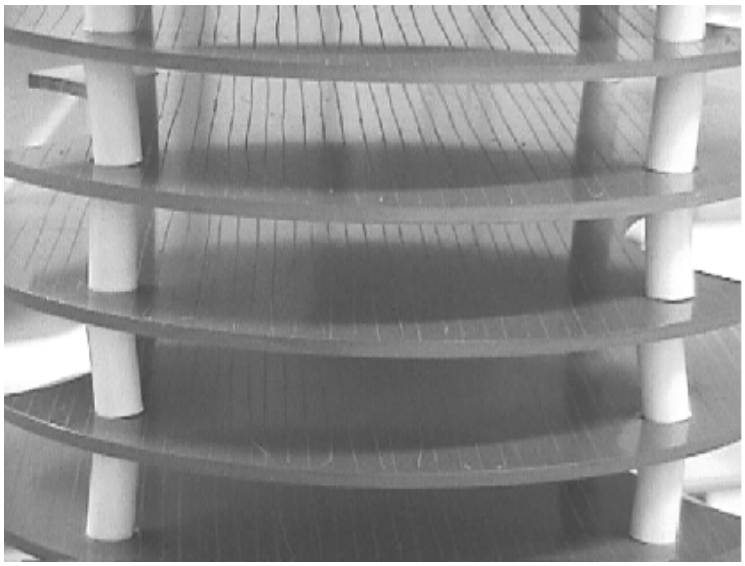

Figure 3 Detail of the BPT plates. In white, the exact shape of each plate is shown. →

Most of the parts of the reactor were built with PVC, including the tower bodies and the plates. The space between consecutive plates was set to 30 mm, but can be increased or diminished using tubes of any selected height. The scratched surfaces of the plates were intended to make adhesion easier.
P. putida was the biodegrading microorganism. Toluene was the sole carbon source. The liquid phase carried the minerals and buffers needed to operate at *pH* close to seven.
MS (mass spectrometry) was used to monitor the removal of toluene.
The biomass was checked for activity by respirometry.
The effluent simulation was achieved with the mixing chamber described in Peixoto e Mota (1997). Toluene was mixed with air from the compressed air system.
A fermentor associated with the reactor allowed the control of temperature and *pH*.

Results and Discussion

Previous works with the same columns packed with 20 mm PVC Raschig rings, showed high removal efficiencies, but proved that it was very difficult to overcome the mentioned problems. Even with a high surface area and porosity, the bacterial growth reduced significantly those parameters in a short time. Besides, channelling occurred. A much larger contact surface was drastically reduced quickly. Ultimately the flow used a single last channel and the process had to stop.

In theory, the available surface in a BPT is a tenth of the surface in a BTF, considering the same total volume. In fact, the new design proved to ensure a stable operation for long periods, as well as high VOC removal. Besides the higher stability BPT ensures a constant surface area and no clogging. There is no need for backwashing or sedimentation. The surface area and the space between plates can be designed for the desired operating time. The operation can be kept virtually forever, since the plates can be periodically replaced. The disposal of the newly formed biomass is also much easier than in the BTF.

As can be seen in figures 4, 5 and 6, the biofilm growth occurs on the upper surface of each plate. The plates at the bottom of each module have thicker biofilms than the upper ones, due to the higher concentration of toluene in the entrance. The first module, which receives the higher dose, is the one that shows the thickest films, reaching over 15 mm until needing to be replaced.

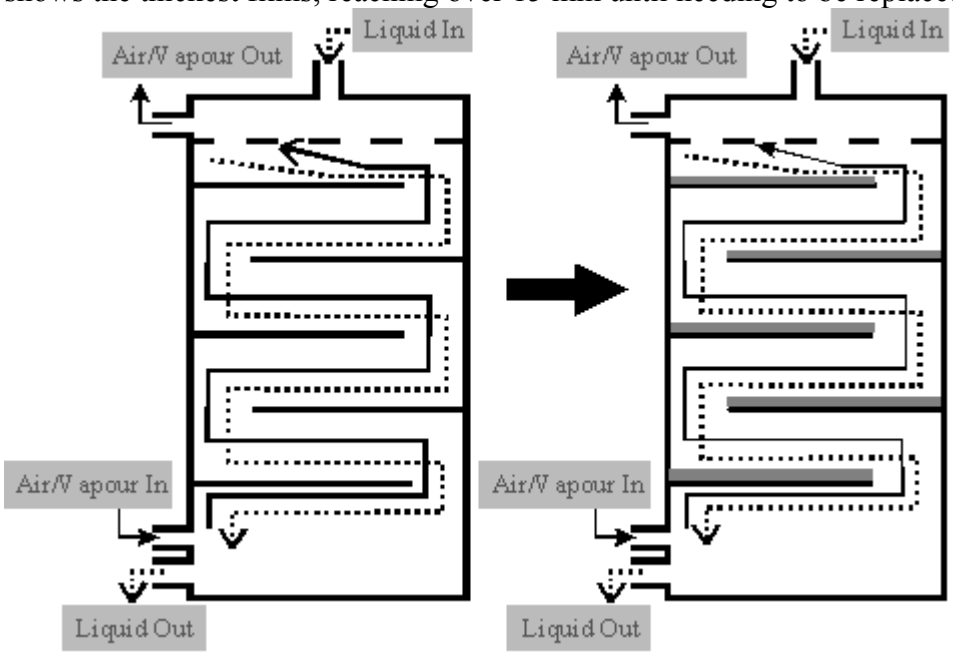

Figure 4 Simplified sche-matics of the BPT, with only 5 plates, to better visualize the directions of both flows and the attached biofilm on the upper surface of the plates.

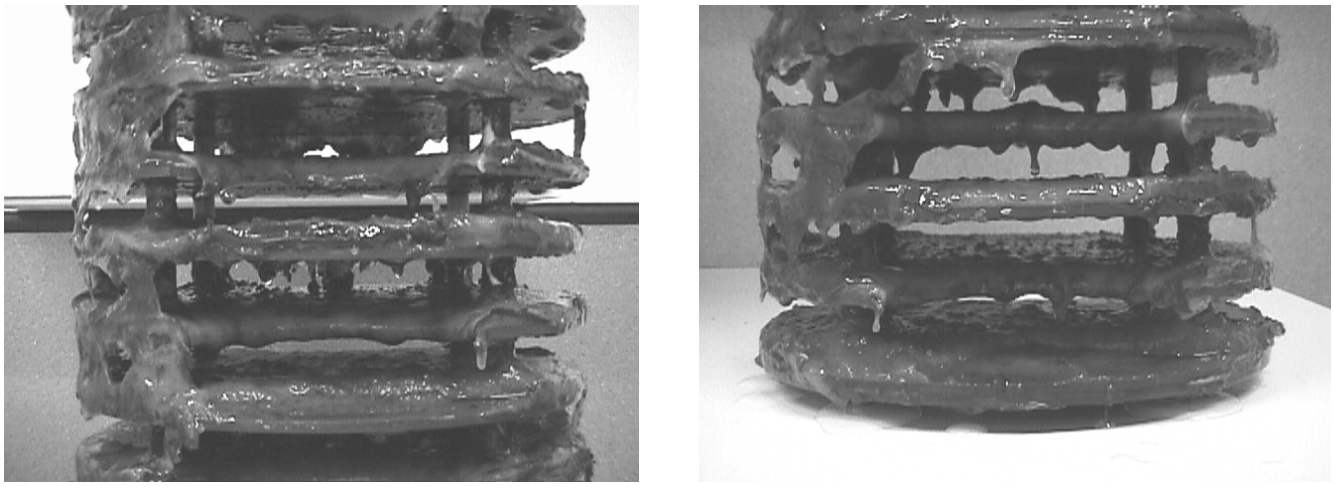

Figure 5 Photographs of the bottom plates of the first (left) and second module (right) showing the biofim growth differences on the BPT plates.

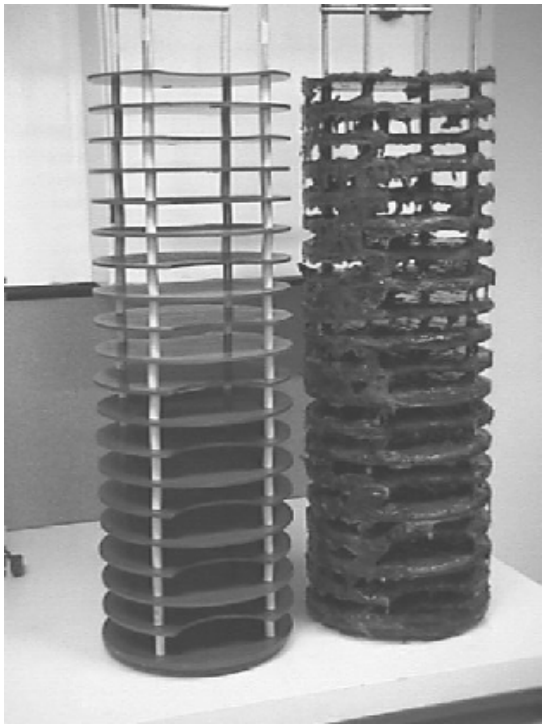

Figure 6 Side by side, two sets of plates showing the difference between the clean plates and the same plates after the bacterial adhesion and growth.

Oxygen uptake rate measurements were made to find out if there were great activity differences between different plates and between the surface and inside the biofim. Samples of superficial layers (about 1 mm thick) of each plate were taken. From the thicker biofilms were also made samples at two different depths (middle and base), besides the top layer. The respiratory activity (mass of oxygen per mass of volatile solids per time) was similar [about 0.11 mg/(g s)] for the superficial samples of all plates, showing some difference (up to about 20 %) for the lower ones where it was higher. The middle samples had almost zero activity [0.01 mg/(g s) or less] and none of the base samples showed any activity. For the respirometry, the carbon source was phenol.

Conclusions

Although the research on the BPT is still going on, it is clear that this design definitely solves the above mentioned problems. The use of this new concept of reactor proved to be suited to solve the problems related to the operation of VOC removal bioreactors, namely channelling and clogging.

In this way, the performance can be quite stable and the constant surface contact area makes easy to model and scale up the process, because the activity of the biofilm is kept approximately constant along the operation. Besides, with the BPT, the possibility of sampling the biofilm for analysis is very easy.

The flow problems, if any will arise, can be solved by removing the plates and then placing them back, after observation and correction. Little disturbance will be added to the operation by these procedures, because little biofilm disruption will occur.

Assays to quantify the VOC removal are now going on. In the future, different bacteria, plate shapes and distances between plates will be tested. The possibility of using different bacteria in different modules will also be considered.

References

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