# Study of the biomass accumulation from inoculation to clogging in a biofilter treating toluene at high loads

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Biofiltration employs the metabolic activity of microorganisms immobilized on a packing material to degrade gas phase pollutants which are the energy source for microbial growth. However, biomass accumulation is one of the most critical parameters that need to be controlled along the operation of biofilters and biotrickling filters in order to achieve stable performance for long term operation. The excess of biomass inside the bioreactor significantly increases pressure drop, which ultimately may lead to wash part of the biomass from the system or to force the replacement of the support media. Additionally, excess biomass implies an increased operation cost (due to pressure drop increases) coupled to a reduced removal efficiency due to reduced specific surface areas and porosities. In addition, potential channeling because of non-uniform biomass growth might occur. Moreover, most of dynamic mathematical models in biofiltration rarely incorporate biomass accumulation processes meaning that predicted results could differ significantly from experimental data in the case of high loads of pollutant.

Several authors have addressed biomass growth and modeling from different approaches. Alonso et al. (1997)[1] concluded that the excessive accumulation of biomass in a reactor has a negative effect on contaminant removal efficiency. The backwashing technique was showed as a useful technique to avoid negative conditions of operation. Nevertheless, the corresponding model considers a homogeneous biomass for one type of microbial species. Deront et al. (1998)[2] evaluated the possibility of following the biomass growth by pressure drop measurements without monitoring other parameters like respiratory activity at the same time. Okkerse et al. (1999)[3] incorporated an active biomass fraction and inert biomass fraction to distinguish microbial components in the biofilm phase but not achieving biofilter clogging in the experimental operation.

In the present work, a lab-scale biofilter treating high loads of toluene was designed in order to quantify and understand biomass accumulation towards future modeling of the system. Pressure drop, reactor weight increase, carbon dioxide production, oxygen consumption, liquid pH, total volatile solids, biomass nitrogen content, optical density of the leachate and toluene gas phase abatement were monitored to characterize biomass growth. Parameters were monitored in the evolution of the biofilter from the inoculation to a forced clogging episode in five sampling ports along the height of the biofilter to determine the corresponding profiles during the period of operation. Biofilter performance was followed for 55 days of operation until pressure drop reached values above 30 $cmH_2O \cdot m^{-1}$. Subsequently, inlet toluene load was stopped and the development of the biofilter was observed in order to quantify the detachment of the biomass from the support media under starvation conditions. After 20 days without inlet feed, the biofilter was restarted to determine the competence of biomass for recovering the capacity to abate pollutant for a period of 45 days.

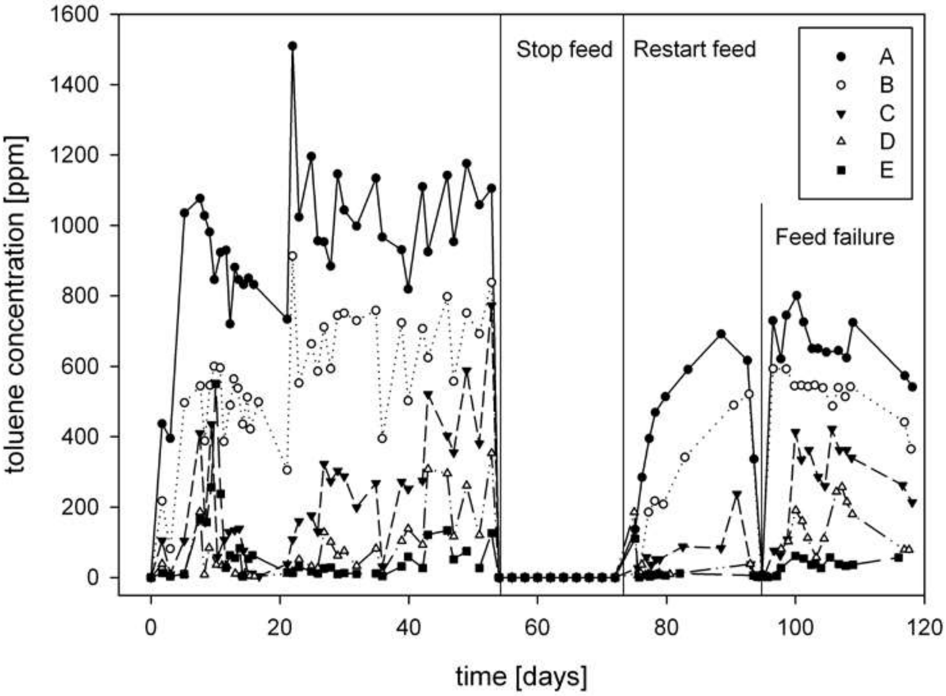


Figure 1. Evolution of toluene concentrations in the operation of the biofilter at the reactor inlet (A), first module (B), second module (C), third module (D) and reactor outlet (E).

The biofilter, with a total volume of 16 liters, was inoculated with activated sludge from a waste water treatment plant. After 72 hours of operation, with an inlet load of 200 $g \cdot m^{-3} \cdot h^{-1}$ and an empty bed residence time of 35 seconds, the removal efficiency was around 97% in the half of the total height of the reactor (Figure 1). Afterwards, the inlet load was increased up to 600 $g \cdot m^{-3} \cdot h^{-1}$ and the metabolic activity was detected in the whole biofilter achieving a removal efficiency close to 99.5% in the outlet stream after 2 days. Microorganism activity was practically kept at the same elimination capacity for 45 days (Figure 1) until the clogging episode was detected (Figure 2). Some modules of the reactor showed an elimination capacity superior to 1000 $g \cdot m^{-3} \cdot h^{-1}$ in specific periods of time. Previous works achieving such high elimination capacities have not been found in the literature.

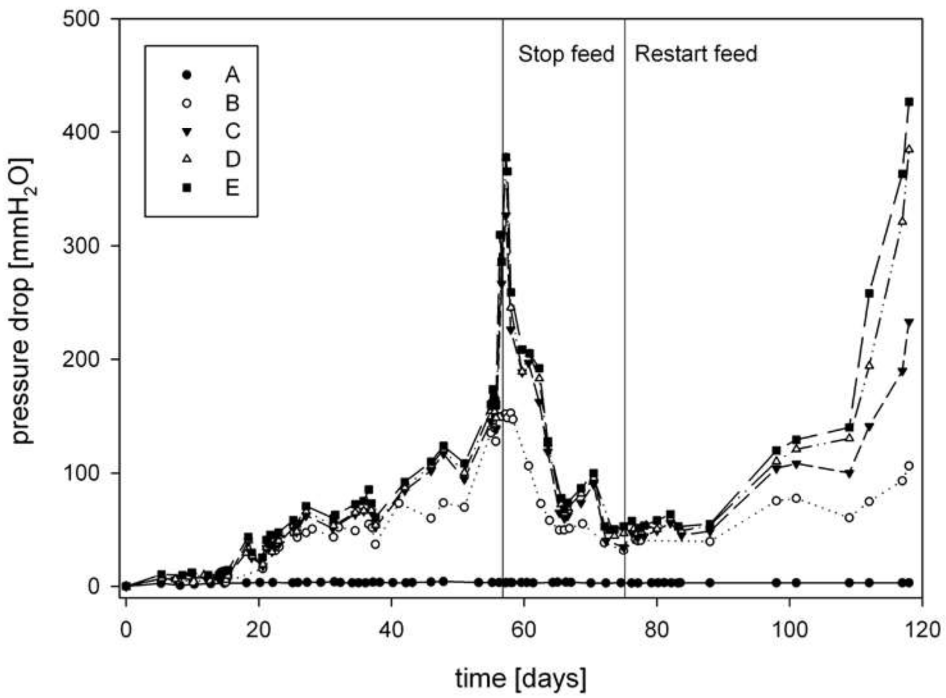


Figure 2. Evolution of differential pressures in the operation of the biofilter at the reactor inlet (A), first module (B), second module (C), third module (D) and reactor outlet (E).

During the interruption of feed, watering and collecting of leachate was kept. Biomass detachment from the packing material was related to the decrease in the pressure drop (until 5 $cmH_2O \cdot m^{-1}$) and the increase in the nitrogen content in the leachate (data not shown). In this period, although the pollutant inlet was closed, carbon dioxide production reached a value of 70 $g \cdot m^{-3} \cdot h^{-1}$, which indicates that the biomass was not completely inactive after 20 days of starvation. It is supposed that the organic matter of packing material, the immobilized biomass and the nutrients incorporated with the irrigation water were enough to maintain partially active the biomass. The rapid decrease of pressure drop in this period demonstrates watering is an effective technique to wash the excess of biomass accumulated in the biofilter.

In the latter period, from day 75, the biofilter was progressively fed with toluene until an inlet load of 390 $g \cdot m^{-3} \cdot h^{-1}$. Immediately, after few hours, the removal efficiency was once again close to 99%, reflecting that biomass was not completely inactive and a rapid acclimatization of microorganisms after the long starvation period. On day 95 a feed failure was registered but the operation was rapidly recuperated. Thus, biofilter was able to cope with intermittent loads without being substantially affected in the operation. In this period, after 45 days of operation, pressure drop increased up to 40 $cmH_2O \cdot m^{-1}$. The short time to achieve this maximum acceptable value of head loss is partially explained by the decrease of frequency in the water irrigation (1L each 3 days). Apart from pressure drop, other parameters related to biomass accumulation as carbon dioxide production and oxygen consumption show a consistent evolution with present results (data not shown). Otherwise, the total weight of biomass increased up to 5500 g in the first period, subsequently decreased 1000 g in the starving period and finally achieved a value of 6000 g after the 120 days of operation.

In conclusion, results demonstrate that high loads of toluene previously not reported can be eliminated by biofiltration. However, it is necessary a strategy to control excess biomass accumulation avoiding reactor clogging to ensure a long time operation. Moreover, present results demonstrated that biofilter is able to recover rapidly the activity after several weeks of starving. Finally, experimental data collected during the operation time permitted to observe significant variations in the main parameters related to biomass accumulation which should permit to calibrate and validate a mathematical model which incorporates the biomass growth in the expressions describing the processes involved in a biofilter system.

References:

1. Alonso, C.; Suidan, M.T.; Sorial, G.A.; Smith, F.L.; Biswas, P.; Smith, P.J., Brenner, R.C., Gas treatment in trickle-bed biofilters: biomass, how much is enough? Biotechnology and Bioengineering. **54** (6):583-594 (1997).

2. Deront, M.; Samb, F.M.; Adler, N.; Péringer, P., Biomass growth monitoring using pressure drop in a concurrent biofilter. Biotechnology and Bioengineering. **60** (1): 97-107 (1998).

3. Okkerse, W.J.H.; Ottengraf, S.P.P.; Osinga-Kupiers, B.; Okkerse, M., Biomass accumulation and clogging in biotrickling filters for waste gas treatment. Evaluation of a dynamic model using dichloromethane as a model pollutant. Biotechnology and Bioengineering. **63** (4): 418-430 (1999).