Inocula selection for VOC removal in the non-clogging Biological Plate Tower

Manuel Mota, João M. Peixoto*
[1]IBB – Institute for Biotechnology and Bioengineering, Centre of Biological Engineering, University of Minho, Campus de Gualtar, 4710–057 Braga, Portugal

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To obtain the best performance in biological reactors, an appropriate selection of microorganisms – the inoculum – is usually the first step. Three different sources of microorganisms were tested in batch and in a continuous reactor – the Biological Plate Tower, BPT – to assess the best conditions for biomass production due to the oxidation of volatile organic compounds – VOCs –, such as phenol, for batch, and toluene, for BPT experiments. Many researchers prefer to use a pure species that is known to have good performance degrading a particular one or a mixture of similar pollutants. In order to keep it from being contaminated by other microorganisms, special care must always be taken. In nature, the occurrence of pure species is very unusual. If natural conditions are to be simulated, then complex inocula should be preferred. The three inocula used were: i) *Pseudomonas putida* ATCC 17514. This bacterium had already proved its good properties in the biodegradation of toluene in several works, namely as the inoculum of a biotrickling filter (Peixoto and Mota, 1998); ii) A sample of activated sludge from a municipal wastewater treatment plant. Complex mixtures of microorganisms (e.g., bacteria, fungi and protozoa) are present in activated sludge. The great variety of compounds you can find in municipal wastewaters leads to the development of many different microorganisms. iii) An activated sludge sample from an industrial wastewater plant was the third source of microorganisms. Petrochemical industries produce wastewaters containing a great variety of compounds, where the aromatic group is included (e.g., benzene, toluene, phenol and xylenes). The ones with low molecular weights are all VOCs. Most inocula must go through an acclimatization period (that may last from minutes to months) before they are able to degrade the compounds at a desired rate. Inocula from environments where the microorganisms are already in contact with the pollutants have usually shorter times for acclimatization (enzyme induction).

For air pollution control, when VOCs and odors are the pollutants, there are three main classical biological solutions: biowashers (bioscrubbers), biotrickling filters and biofilters. The big mistake in the transposition from physical-chemical to biological reactors is to forget that the presence of biofilms completely changes the behavior and performance of the reactor. Biofilm growth is chaotic and never tridimensionally homogeneous on a random packing. Oriented packing has better results but not yet good enough. A good physical-chemical reactor does not have to be a good biological one and it is indeed a poor option in many situations (Sercu et al, 2006). Four phase reactors (liquid, gas, solid support and biofilm) always bring about hydrodynamic problems. Sloughing, channeling and clogging always occur. Good removal efficiency only makes it happen faster. Measures to deal with clogging are mostly oriented to limit the growth of the microorganisms, which are contradictory actions. Indeed, the best performance is achieved when the biofilm activity is the highest, which implies a maximum growth rate.

To solve these problems and make the process easy to operate steadily for a long time, a new concept of reactor – BPT – was designed and tested with air polluted with VOCs. The effluent simulation was achieved with the mixing chamber described in Peixoto and Mota (1997).

* Corresponding author. Tel + 351-253-604400. E-mail:jmp@deb.uminho.pt

The observation of the growth on the plane surfaces (top liquid distributor, base plate) of a biotrickling filter suggested a design based on horizontal surfaces. The BPT is a modular reactor. Each module contains a pile of parallel circular plates, with a single hole on the border. A new tower, with rectangular plates, is being built for future research. The plates are placed in such a way that the holes will alternate (180^o) from one to the next plate. 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 bacteria attach to their top surface. The distance between plates is set according to the desired operating time. When the biomass growth causes the limiting pressure drop then a fresh one replaces the saturated module. If convenient, different modules may be seeded with different species. The performance is quite stable (the biofilm activity, surface-dependent, is kept approximately constant) and the constant surface contact area makes easy to model and scale up the process. The total surface area and the space between plates can be designed for the desired operating time and removal efficiency (Sercu et al, 2006).
The batch studies (phenol degradation) showed best results for the petrochemical plant inoculum: greater phenol concentration tolerance, and greater removal rate (up to about 90 % with a consumption rate of 0.23 h^{-1}). The specific growth rate of the microbial community was 0.14 h^{-1}, with 5 h acclimatization time. The global yield (biomass produced divided by phenol mass consumed) was 0.6 g/g.
Continuous assays with the BPT (toluene degradation) also presented best results for the petrochemical plant inoculum when biofilm activity, and both protein and polysaccharide quantities were considered.
In previous works using *Pseudomonas putida* ATCC 17514, the assays to quantify the VOC removal were done with toluene, benzene and xylene. Three contacting times were implemented (3.0 min, 1.8 min e 1.3 min). For the longer one, the average percent removals were 92 %, for toluene (with inlet concentrations up to 19 g/m^3), 96 %, for benzene (with inlet concentrations up to 16 g/m^3), and 85 %, for xylene (inlet concentrations up to 5 g/m^3). The simultaneous removal of the three VOCs, all together, was also checked. The bacteria tolerance to temperature (between 15 ℃ and 47 ℃) and to pH (from 2.2 to 10.6), one at a time, was also studied. Inside the biofilm, the bacteria proved to be very well adapted to those wide changes, and little effect on the removals was felt. The same happened when the liquid flow was severely reduced and finally stopped. No significant effect was detected in the reactor performance after some hours of operation without any liquid flow.

References

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