
Relationship between surface properties and efficiency of biocarriers

The role of the carrier material in the formation of biofilms

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Due to their significantly higher performance and process stability, microbial cells fixed in biofilms are increasingly being used in the biological treatment of wastewater and polluted air. They are generated by the microbial colonization of solid surfaces, biocarriers and subsequent fixation of the cells.

The activity of biofilms depends primarily on the rapid colonization of the carriers with as many different strains as possible and their good adhesion. These correlations have not yet been sufficiently clarified. So far in the development of the carriers the attention has been focused usually on the creation of the largest possible surfaces of specially shaped plastic bodies. In addition to clarification of the above-mentioned causes, the aim of the R&D activities was the development of optimized carriers that enable more strong and active biofilms. An optimal bio carrier should support

- rapid microbial colonization,
- rapid biofilm formation and start of bioprocesses, as well as
- high conversion rates at high process stability and
- low energy consumption for aeration and fluidization..

Surface-modified biocarriers

Because of its large surface area, porosity and flexibility, abrasion-resistant, open-pored flexible polyurethane foam was chosen as the base material. Cubes produced from this were coated with surface-active pigments such as activated carbon, iron oxides, etc. and tested for their applicability as a biocarrier. (Fig. 1, Table 1),

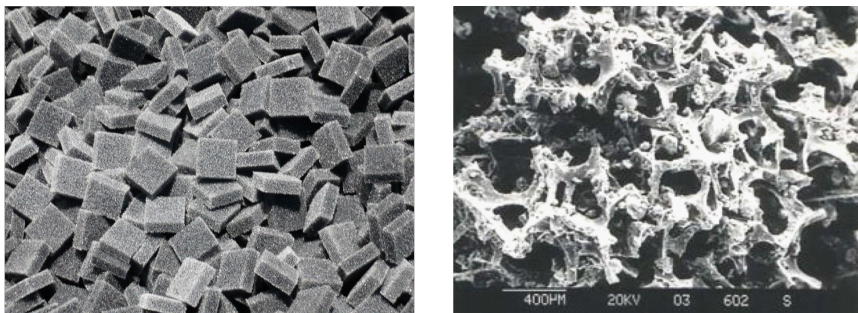


Fig. 1 Delivery form (20x20x7mm) of adsorbent PU carrier and cross section

The coated, 20x20x7 mm cubes had adsorbing surfaces between approx. 5,000 and 15,000 m²/m³, which significantly improved their application properties.

Faster colonization of surfaces and start of bioprocesses

Parallel experiments on the anaerobic degradation of o-chlorobenzoate (OCB) by biofilms formed on differently doped carriers showed that the carriers with the highest coal content (LEVAPOR) were colonized by the suspended cells to over 90% after about 180 minutes. The same bioreactor started the fastest and also achieved the highest gas development, or the highest conversion rate (Fig.2).

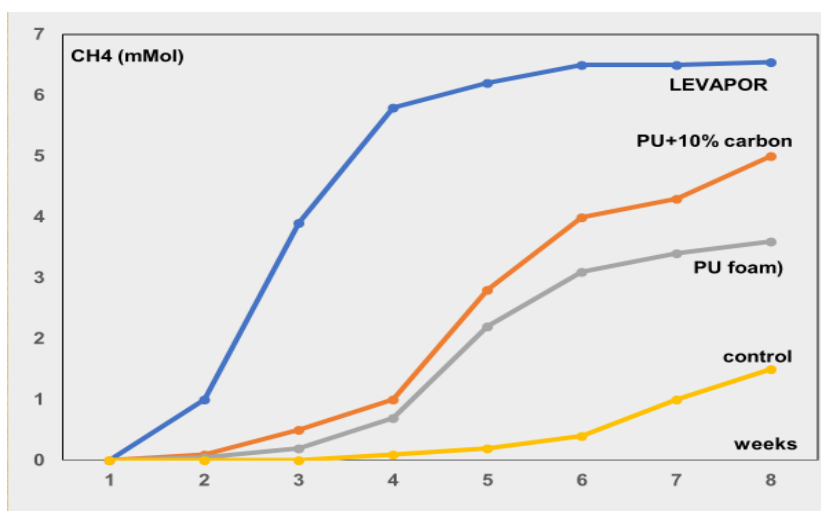


Fig. 2 The effect of carbon content on biodegradation rate of o-chlorobenzoate

Property	PU carrier	Plastic carrier
Total surface (m ² /m ³)	15.000	500 to 1000
Adsorbing capacity	very high	low
Reactor filling , %	12 – 15	30 - 70
Porosity , %	90 - 95	70 - 90
Water uptake , % by wt.	up to 250	negligible
Microbial colonisation	120 – 180 min.	several weeks
Fluidisation with air (m ³ /m ² *h)	5 - 7	10-11

Tab. 1 Properties of LEVAPOR vs. plastic carrier

Higher achievable cell density and biodiversity

In a comparative experiment in three MBBR reactors operated in parallel with municipal wastewater, these were inoculated with 3600 mg/L activated sludge each and filled after start-up with the same amounts of plastic or adsorbing PU carriers.

Due to the lack of secondary clarifiers, the suspended activated sludge was for the most part quickly washed out of the MBBR reactors, whereby the fixed cell mass gradually increased due to the biofilm formation, namely

- on the surface of the plastic substrates from 200 mg/L to 670 mg/L, while
- the PU carriers directly adsorbed about 1200 mg/L of the biomass used, it quickly increased to 2500 mg/L and remained at this level (Fig.3).

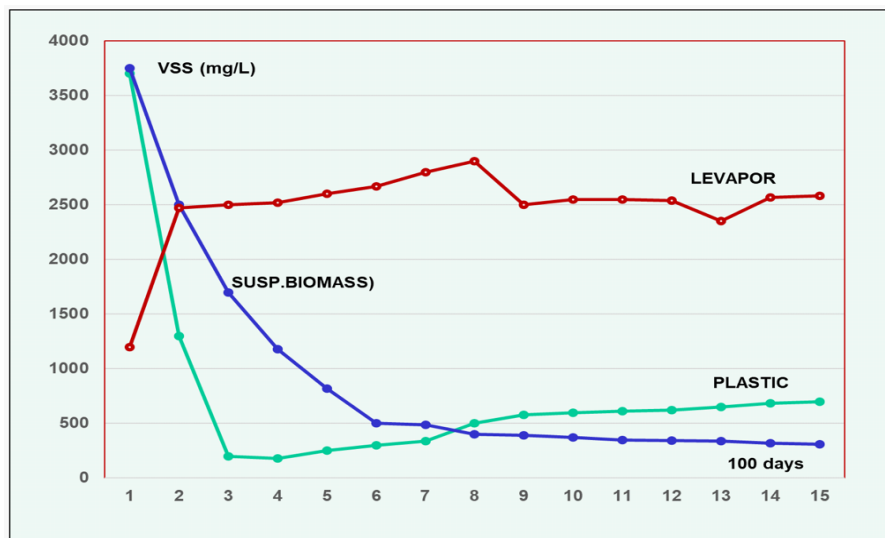


Fig. 3. Development of biofilm mass on LEVAPOR and plastic carriers

The floral analysis of the biofilm has shown that the biofilm on the PU carrier showed a significantly higher biodiversity than that on the plastic carrier, especially the ratio of nitrite-oxidizing organisms *Nitrospira* was higher, resulting in higher nitrification performance of this biofilm.

The influence of adsorbing surfaces on bioprocesses

During the biodegradation of the toxic 2-chloroaniline (2-CA), it was first adsorbed while reducing the toxicity of the medium (Fig.4). after which an undisturbed degradation of the 2-CA took place, while the degradation with suspended cells was inhibited. The amount of released chloride ions indicates the extensive degradation of 2-CA.

This new mechanism, consisting of adsorption and easier start-up, enables the biodegradation of even low-degradable, hazardous substances.

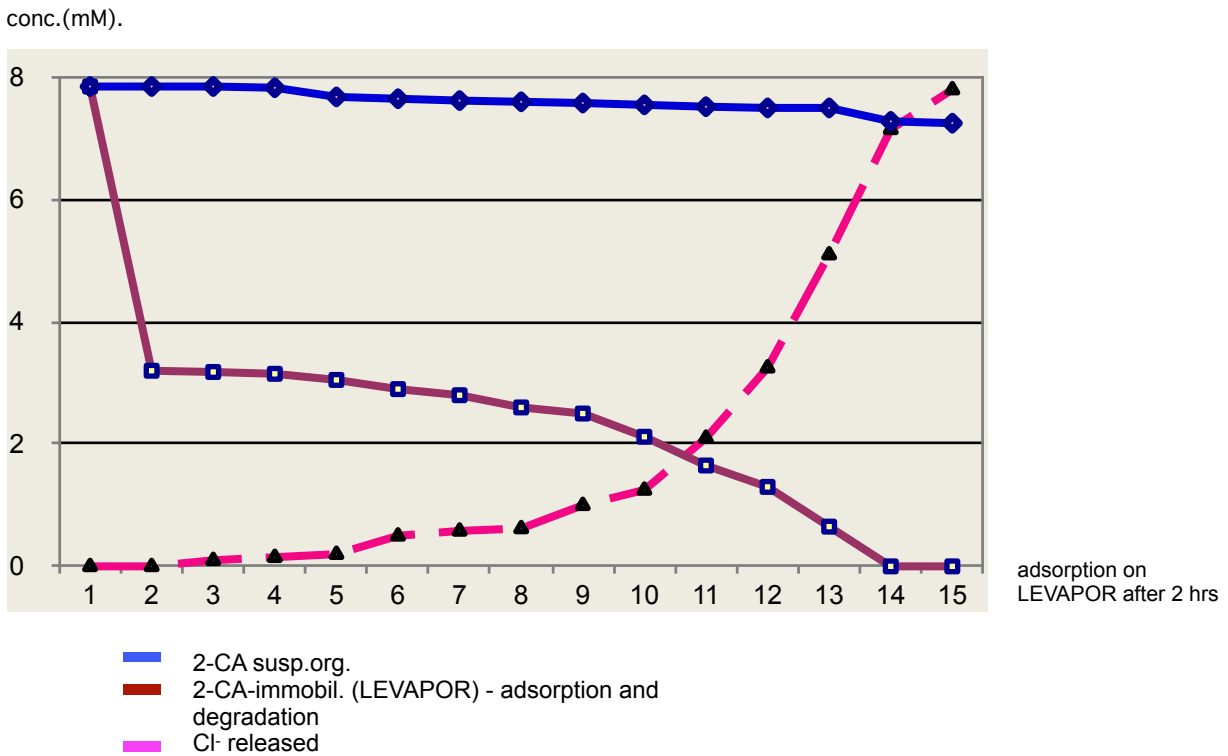


Fig. 4 Degradation of 1000 mg/L (7,8 mM) 2-chloroanilin by suspended (◆), resp. immobilised (◻) adapted microorganisms.

Increased degradation performance (space-time yield)

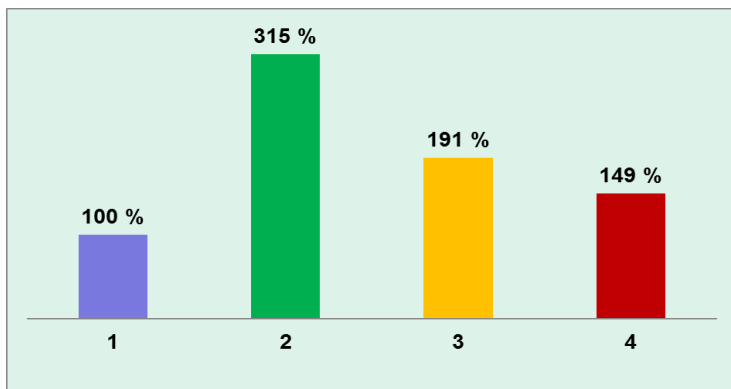


Fig. 5 Effect of carrier material on nitrification of (NH₄+NO₂N)-N in an aquaculture (1- PE-plastic , 2- LEVAPOR , 3- PU-foam und 4-Ceramic)

In nitrification, in the presence of various carriers, the reactor operated with PU carriers achieved at effluent values of NH₄N < 0.2 mg/L and NO₂N < 0.1 mg/L about three times higher performance than reactors (Fig. 5).

In the anaerobic treatment of toxic pulp mill effluents the reactor operated with adsorbing carriers has eliminated at volumetric loading rates of $L_v \sim 3.0 \text{ g COD/L*day}$. about three times more COD than that with suspended cells (Fig.6). In practice, this meant the construction of anaerobic reactors with a volume of only 18,000 m³ instead of the originally planned 65,000 m³ with alternative technology.

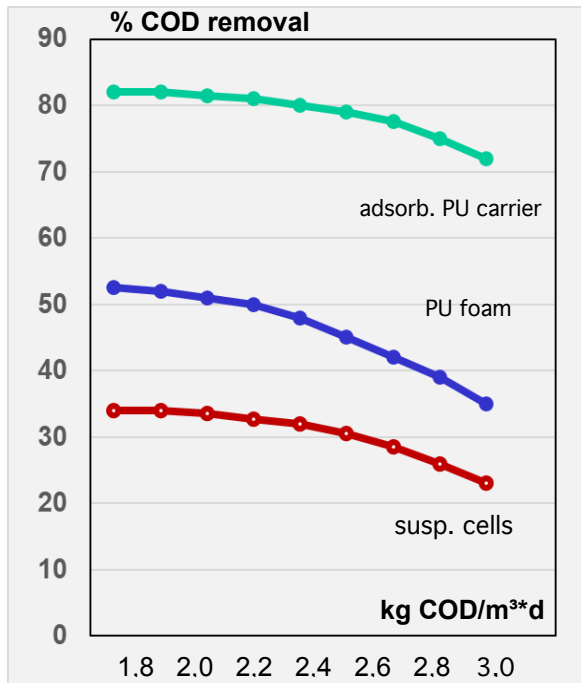


Fig. 6 Effect of carrier material on COD removal in the anaerobic treatment of toxic pulp mill effluents

Higher stability of bioprocesses

Biofilms enable more stable bioprocesses. During the commissioning of a wastewater treatment plant for the treatment of toxic pulp mill effluents, two anaerobic reactors with PU carriers were started, but the third with suspended cells. Already after the start, the reactors operated with biofilms showed higher degradation capacities (Fig. 7). After an operational disruption, the performance of the reactor with suspended bacteria largely collapsed, while the two biofilm reactors recovered relatively quickly .

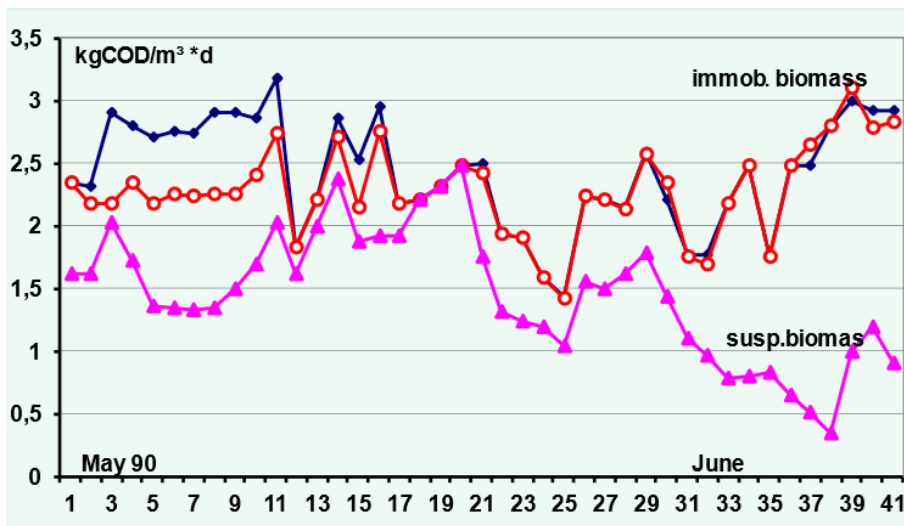


Fig. 7. Effect of immobilisation on process stability

Low reactor filling, low energy consumption

Due to the higher activity of the biofilms formed on adsorbing PU carriers, 12 to 15 % fillings are sufficient for doubling to tripling the space-time yields, which also reduces the energy requirement for aeration and carrier fluidization. While aeration densities of already 5 to 7 m³/m²*h air are sufficient for the aeration and fluidization of the wastewater containing 12 to 15 vol.% PU carrier, with 30 to 40 vol.% plastic carriers practically the double air volume of 10 to 11 m³/m²*h is required, corresponding to significantly higher energy consumption.

As the examples shown show, large, adsorbing surfaces of porous impregnated PU foam carriers play a decisive role in the formation of stable and active biofilms and enable fast-starting, stable and powerful bioprocesses. Thus, these composite materials can be optimally used as carriers for biofilms.