Mutag BioChip™, the ultimate MBBR carrier for biological wastewater treatment

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German company Multi Umwelttechnologie AG has over 17 years of experience in the operation of carrier media used for immobilising microorganisms in biological wastewater treatment plants and systems. During this time, we have used almost every known biofilm carrier in numerous different large-scale plants, in different types of wastewater as well as in different fields of application. The knowledge that we gained in result, along with a wide data base, enables us to make a well-founded assessment of the specific performance data of several biofilm carriers which were in some cases extremely different from each other. As Multi Umwelttechnologie AG has at no time been dependent from any particular supplier, we were able to implement targeted optimization either of the carrier itself or of the process conditions, based on the operational experience we gained. Here, the emphasis was on minimising operational problems arising from the shortcomings of "conventional" biofilm carrier media, which are not to be neglected nowadays. The thorough implementation of our requirements on an optimal biofilm carrier led to one final result named Mutag BioChip™. From our point of view, it is currently the "best carrier available" notably for purifying types of wastewater that are difficult to treat.

1. How the Mutag BioChip™ works

The particular functionality as well as the efficiency of the Mutag BioChip™ can be explained best by orientating on the characteristic MBBR process conditions (MBBR = moving bed biofilm reactor). A crucial prerequisite for the biological removal of wastewater components in the MBBR process is the immobilisation of the microorganisms on the surface of carrier elements. Here, the efficiency of the biological removal is determined by the carrier's "active" surface area. This comes along with the following carrier requirements: Firstly, there must be available sufficient protected effective surface area in order to enable the microorganisms to survive and to reproduce themselves in these areas; and secondly, it is necessary to realise a maximum of mass transfer (substrate, oxygen, metabolic products) between microorganisms and wastewater. At first glance, the simultaneous fulfilling of both of these requirements seems to be a procedural contradiction, but this can be disproved as follows:

Firstly, the error of maximising the volumetric surface area (in m²/m³ of carrier elements). Of course, it is possible to produce carrier media possessing an extremely high porosity, but it is also a fact that these pores must be accessible to the microorganisms as a potential habitat. It is easy to understand that this is hardly possible for cavities inside a carrier. If, as it is commonly the case, the transformation efficiency is correlated to the porosity, this represents a fatal distortion of the actual relations.

This is different in the case of the Mutag Biochip™: Here, a relatively thin and mainly open carrier provides an extremely large surface area in which the microorganisms can form colonies in protected pores, whereas they still remain in intensive contact with the surrounding fluid (wastewater). Consequently, the microorganisms can be optimally supplied with nutrients and the metabolic products are efficiently removed from them; this explains at least partially the effectiveness and high biodegradation efficiency of the Mutag BioChip™. Expressed in figures: the a<u>ctive</u> surface of the Mutag BioChip™ is more than 3,000 m²/m³ (Figures no. 1 and 2).

Figure 1: Colonised Mutag BioChip™s

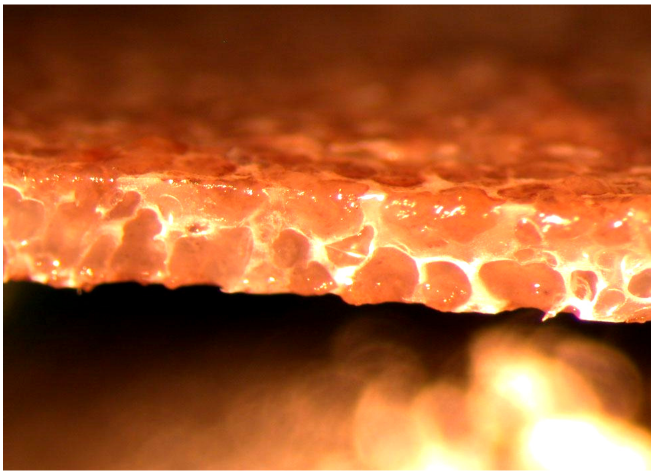

Figure 2: Pore system of the Mutag BioChip™ (cross section)

Next point: Limitation of the biodegradation by "thick" biofilms due to clogging and "non-biological" impurities. Even in cases where a high microbial population density can be established on a carrier; if the structure and / or geometry of the carrier should be inappropriate, the mass transfer into the "deeper" layers of the biofilm is being reduced. Consequently, the biodegradation efficiency of the immobilised biological system is continually reduced during the operation.

Figures no. 3 and 5 show how this can look like with various carrier types and carrier geometries. The consequences resulting from clogged carriers are easily conceivable. However, the countermeasure is very simple. The special geometry of the Mutag BioChip™ enables the hydraulic shear forces acting on the outer surface to intensify, and a self-cleaning process is initiated which constantly renews the carrier's active surface. This process effectively prevents from the limitation of the biodegradation efficiency which might be caused by mass transfer obstacles.


Figure 3: Clogged carrier media (paper mill effluent)


Figure 4: Mutag BioChip™ operated in parallel


Figure 5: Mutag BioChip™s and conventional carriers in parallel operation (result)

Problems with the distribution and mixing-in of the carrier are prevented by the parabolic shape. In order to optimise the mass transfer (as already mentioned before), the Mutag BioChip™ is shaped like a parabolic disc. Although it has hence an uncontrollable motion profile (at least seen from a flow-mechanical point of view), the latter has proven to turn out to be extremely positive in this case. In addition to the increased level of turbulence which directly leads to an increase in the mass transfer, the mobility of the individual carrier elements is effectively increased in the cluster. This results in a homogeneous distribution of the carriers within the entire reaction tank volume whereas the formation of any "dead zones" is effectively reduced.

2. Operational results

Of course, any theoretical considerations require the verification of the projected benefits within a confidence-building time frame. So far, we are able to fall back on three years worth of operational experience with the Mutag BioChip™; during this time it was possible in some cases to operate systems in parallel in order to compare the Mutag BioChip™ with "conventional" carrier media. Unfortunately, not all operational results can be listed at this point, as this would understandably exceed the scope of this article. However, on the basis of the selected case examples, it is possible to meaningfully document the efficiency of the Mutag BioChip™. We consider it important to point out that the results listed herein are of fundamental nature, allowing transferring them to other types of wastewater and treatment applications.

Related to the direct comparison of biodegradation efficiency, the upgrading of a high-load stage provided us with valuable results in the treatment of the effluent of a paper mill. In this case, the major task was to increase the system capacity from 25,000 kg COD/d up to 50,000 kg COD/d, and to keep the paper production running throughout the complete civil works phase. For this reason, the following procedure was chosen: Initially, the existing high-load reactor filled with conventional carriers was kept in operation, whereas a similar second tank was erected in parallel. After the installation of the mechanical equipment (Figures 6 and 7), around 7% of the old reactor's carrier volume in the form of Mutag BioChip™ carriers were put into the new high-load reactor in order to get an initial orientation; subsequently, both high-load stages were fed with the similar wastewater volume flow rate. Based on the positive findings gained here, the BioChip volume was increased in a second step to 11% related to the "conventional" carrier volume that would normally have been required. Figure no. 8 shows the results that were obtained afterwards. It is clearly obvious that the Mutag BioChip™ reactor now attained the same removal efficiency as the old reactor did, so there was no need to further increase the BioChip volume. In direct comparison with the conventional carrier media, the increase in the degradation efficiency by the factor of nearly 10 achieved by Mutag-BioChip™ was proven clearly and impressively.

Based on both these findings and the stable operating results of the new Mutag BioChip™ high-load stage, the old reactor was put out of operation and modified. Now, both stages are operated with the Mutag BioChip™ technology and reliably attain the required treated effluent parameters. With regard to the scope of the entire upgrading, it is worth mentioning for the sake of completeness that at least 1,000 m^3/h of sewage water will be treated here in the future whereas an upgrade of the low-load activated sludge stage is also envisaged.

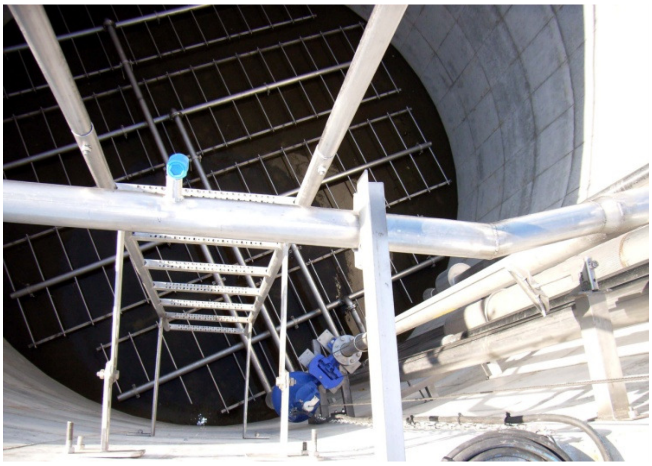

Figure 6: Mutag BioChip™ high-load aeration system

Figure 7: Mutag BioChip™ high-load reactor in operation

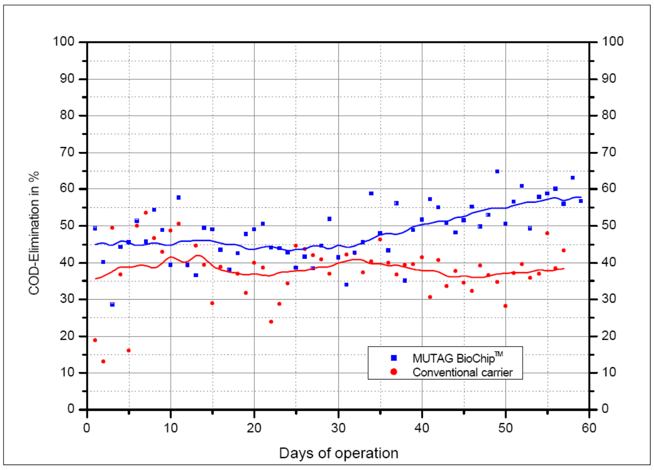

Figure 8: COD removal reactor (old) and Mutag BioChip™ reactor

As a second example and as a further proof of the efficiency of the Mutag BioChip™ also in nitrogen elimination, its use in the nitrification stage of a coke oven effluent treatment plant will be described in the following. Coke oven effluents are not only regarded as difficult to treat – acc. to our experience they can be biologically purified by means of multiple biological stage systems only. Here, particular biodegradation rate requirements have to be fulfilled; this applies especially when taking into consideration the reactor sizes that need to remain within implementable as well as controllable dimensions. Suchlike plants using Mutag BioChip™ carriers have been in continuous operation for more than four years. Converted into population equivalents, the largest of them have a nitrification capacity of around 100,000 PE and 55,000 PE. The BioChip's superiority can be observed here, too. Removal rates of 4-5 kg NH_4-N per m^3 of carrier volume are reliably attained at a constant level, even though the Mutag reactors are smaller by a factor of 5 than the activated sludge tanks which are usually required.

3. Summary and outlook

The Mutag BioChip™ proved to be very adaptable as far as its use in different types of wastewater is concerned. This applies also to the elimination of organic compounds (measured as COD) and nitrogen compounds (e.g. ammonium).

The properties mentioned herein as well as the precise operational results of the Mutag BioChip™ alone illustrate the superiority of this carrier compared to its “conventional” competitors. This applies also to the supplementary system components (aeration & carrier retention system) which optimally support the specific advantages of the Mutag BioChip™.

With regard to the future, it was determined already during the engineering phase of the projects presented herein that there need to be kept available certain capacity reserves whereas the central task was to activate the latter without any structural alterations but “only” by adding more carrier media, if required. Of course, this is limited by procedural aspects which, in a first approach, can be reduced down to the maximally possible fill fraction of the carrier media. Consequently, it is easily understandable that the Mutag BioChip™ system can keep available a reserve capacity which is nearly 10 times higher than it would be possible with conventional wastewater treatment plants.

Notably operators of existing wastewater treatment plants might be enthusiastic about it: Often they have to face the problem that operational upgrades are approved only if the discharged contaminant load remains unchanged. By using the Mutag BioChip™ system, these plants can be upgraded relatively easily, quickly and economically. This applies also to treatment plants which are located far away as the transport costs of the carrier media are normally reduced also by the factor 10 compared to conventional media.

For more information, please visit the following website: http://www.mutag-biochip.com