IMMOBILIZED ACTIVATED CARBON FILTRATION – APPLICATION AND EXAMPLES

NOTC
Product names and filter sheet grades may have changed since the application note was created.

1 Immobilized PAC – overview

Immobilized powdered activated carbon (PAC) is contained in the filter sheets of FILTROX. Nine different filter sheets in three different purity grades are produced within the FILTROX Group. The pore size (misopores, mesopores and macropores) of each CARBOFIL™ filter sheet derives of the used PAC (figure 1). The composition is always a mixture of different PAC immobilized in the filter sheet. Thus, a pore size distribution is generated. However, one pore size dominates in excess. The various pore sizes results from the material which is involved as well as from the activation process. Due to the pore size, various molecules are adsorbed (figure 2).

Immobilized PAC (e.g. in a depth filter sheet or in a lenticular module) is most commonly used in pharmaceutical as well as in the food and beverage industries. The handling, cleaning and time of PAC is considerably higher than working with immobilized PAC.

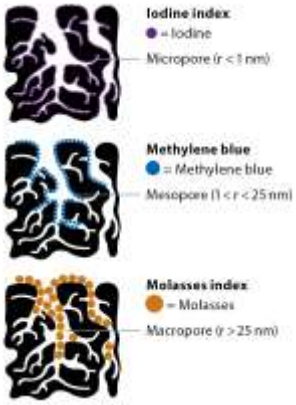


Figure 1:
Pore size indices

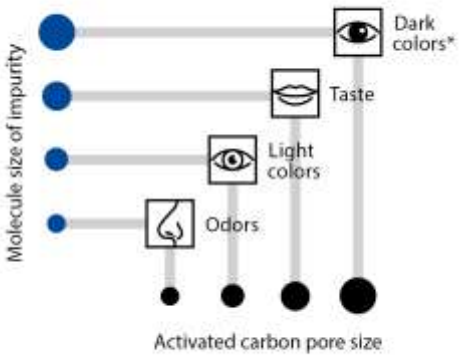


Figure 2:
Role of pore size distribution

The main advantages of immobilized activated carbon compared to loose PAC is the easy scale-up, due to the predictable filtration capacity. Furthermore, the dust explosions risk is minimised and the downstream process is optimised. The reasons are, because firstly, no reactor is used and has to be cleaned after usage and secondly, no activated carbon remains in the desired solution and has to be filtered out in the end. According to a laboratory study, 33% of activated carbon in addition is necessary for the same efficiency as immobilized PAC in a filter sheet.

The following chapters contains application examples for the use of immobilized PAC. The results depends on the product and therefore, it is just an example how a filtration with immobilized PAC could work.

2 Removal of polymorphs

Decolourisation and deodorisation are two of the most common applications of powdered activated carbon. It can be applied in all different industries as chemical, pharma, cosmetic and food & beverage industries. Due to the small pores of the activated carbon, the surface increases and therefore, more molecules can be adsorbed.

Example:

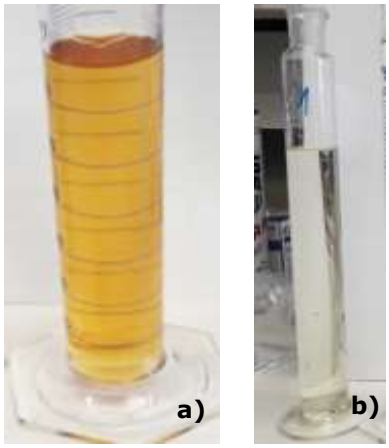
A powdered API should be produced by crystallization. After this process step, a yellow-brown powder as the drug substance is generated from the unfiltered solution (see picture 1 and 2). However, a "white to off-white" powder is required. Due to this requirement, an "out of specification" powder resulted by the crystallization step only.

Picture 1:
Unfiltered API (stirred-up)

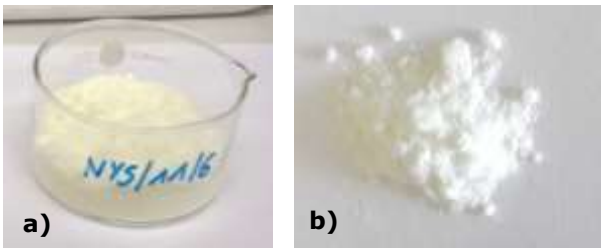
Picture 2:
Powdered API after crystallization

To reach the requirement, various pigments and other particles should be removed by a surface filtration step. A less turbidity filtrate was obtained. Nevertheless, an intense yellow colour was the result, which is shown in picture 3a. Therefore, another process step, to reduce the colour was needed.

After several filtration trials, FILTROX CARBOFIL™ CA was identified as the best performance filtration media for color removal for this application (see picture 3b). Data were designed for 12" lenticular modules in the pilot scale. After the filtration with immobilized PAC and the crystallization step, the API powder resulted as shown in picture 4. With an amount of 0.55 cm²/g product of activated carbon, a better result compared to the first reached color without any filtration step, was achieved. Nevertheless, it was not satisfying yet. With a higher amount of 1.1 cm²/g of activated carbon, the target was reached. In this special case, further lab trials would have been interesting. Less filter area per Gramm activated carbon than 1.1 cm²/g could have been resulted in the same satisfactory outcome.



Picture 3:
API after surface filtration (a, stirred-up) and after CARBOFIL™ CA treatement (b).



Picture 4:
Resulted API powder after fitration with CARBOFIL™ CA and crystallisation. 0.55 cm² (a) and 1.1 cm² (b) activated carbon per gram product was used.

3 Removal of heavy metals

The platinum metal Palladium is widely used for the mediation of reactions for synthesis of biological active compounds. It is often applied near to the end of the overall synthesis due to the tolerance of functional groups. Palladium is only one example which can be removed by immobilized activated carbon. By selecting the required and for each application adjusted filter sheet with immobilized PAC, not only colours or odors can be removed. Also polymorphic substances can be eliminated by a filter of the FILTROX CARBOFIL™ range.

Example:

Palladium is used as a precursor in the Suzuki-Miyaura coupling for an API synthesis (figure 3). Bisaryl intermediate is comprising of more than 500 ppm of palladium. Only 60 ppm are allowed to be present in the bisaryl intermediate. Therefore, a further process step, to reduce palladium from 500 ppm to 60 ppm was needed. Furthermore, this new process step had to be consistent and efficient.

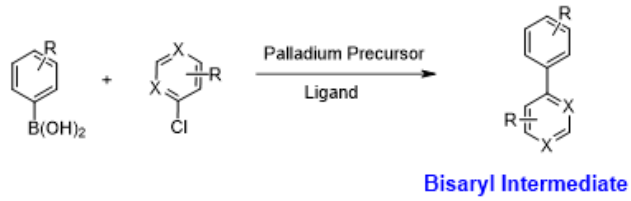


Figure 3:
Synthesis of bisaryl intermediate with Pd as Precursor.

There are different techniques for the removal of palladium (see table 1). None of them is satisfactory, due to various disadvantages. "Not in specification" or strongly fluctuated results were reached by these techniques. The developed process, including the filtration step with CARBOFIL™ CA, is described in table 2. After filtration and crystallization to the final product, a palladium content of 9 ppm was measured by HPLC.

Table 1:
Process steam of palladium removal

Technique for precious metal removal	Pd level in intermediate	Additional costs	Comment
Crystallizsation	> 500 ppm	-	Various solvent system tested
Palladium Scavanger	Not tested	> 15 €/kg	Not priorized due to the high cost contribution
Extration with cysteine	80 – 120 ppm	3 €/kg	Borderline Pd removal – regulatory difficult due to animal origin of cysteine
Extraction with sodium bisulfite	5 – 76 ppm	< 1 €/kg	Process capability not sufficient to assure in-spec product
Extraction with sodium bisulfite and CARBOFIL™ CA treatment	Average 12 ppm	~ 1.5 €/kg	Stable process with in-spec product

Table 2:
Process steam of palladium removal

Process	Palladium content [ppm]
Organic phase after an aquatic purification	533
Organic phase after 2x extraction with $NaHSO_3$	91
Organic phase after 3x extraction with $NaHSO_3$	71
Organic phase after 3x extraction with $NaHSO_3$ and CARBOFIL™ CA treatment	28
Final product	9

So far, an average Palladium content amounts to 40 ppm existed, however, a broad scattering of the achieved results could not be prevented (figure 2). With CARBOFIL™ CA, the average Pd content was reduced to 12 ppm. The Pd removal can be achieved in a cheap way. An overall yield of 83 – 85% was realized with activated carbon treatment. In addition a robust process with less fluctuations was developed.

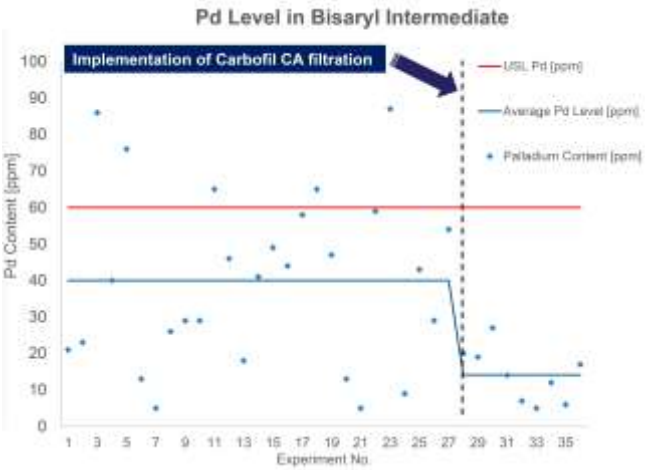


Figure 4:
Palladium content and average Pd level bevor and after filtration with immobilized PAC.

4 Conclusion

Immobilized activated carbon can be ideally used for a wide range of applications. It is a flexible tool for the manufacturing of API's through the entire production cycle. With the broad selection of activated carbons fine-tuned impurities can be filtered out. Furthermore, the scale up is easy and reliable and the downstream process is reduced. By using a filter media, the handling of this one process step is easy and health and safety are avoided. A reduction of the costs is achieved, due to the minimized cleaning steps. Immobilized activated carbon can be applied for e.g. decolourisation or metal removal and recovery. To find the best working carbon grade, the goal of the filtration and the degree of purity has to be defined. Process conditions have a significant impact on the filtration process. Filtration trials shall to be performed.