Backwash Characteristics of Granular Activated Carbons (GAC) from Asia

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Title
Backwashing characteristic of granular activated carbon (GAC) from Asia

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Summary

Different coal based granular activated carbons (GAC) from Asia were investigated according to their backwash characteristics and compared to a conventional coal based GAC from US. Different coal based GAC types show different backwash curves, however it can not be concluded that all GAC from Asia have the same characteristics.

The different GAC types were characterized by more parameters as bulk density, particle size distribution and adsorption capacity. From these parameters it can be derived that the Asia GAC are more inhomogeneous within one carbon charge compared to the US GAC. Correlations among the different parameters can not be established.

Thus the research project shows that the backwash regime has to be adjusted for all GAC types to avoid a carbon loss during the first backwash cycle and to assure an optimal placing into operation of the GAC adsorber.
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1 Backwash characteristics of granular activated carbons (GAC) from Asia

1.1 Situation and Research Incentive

For the removal of trace organic contaminants activated carbon adsorption is a widespread treatment process especially during surface water and bankfiltrate treatment. In most cases granular activated carbons (GAC) in fixed bed adsorbers are used. In the past the GAC used in the process was reactivated after exhaustion due to the fact that the costs for reactivated GAC were about 30 to 40 % lower compared to virgin carbon. Meanwhile the situation has changed. More GAC types are offered on the European market whereas a lot of GAC types are produced in Asia. These activated carbons are less expensive compared to other European and US GAC, and the costs are in the same range as reactivated GAC. Thus water utilities take into consideration the performance of GAC from Asia.

The conformity with the DIN EN 12915 [1] which regulates purity of the activated carbon is the first criterion for all GAC. This information is provided by the carbon supplier. For the practical application more criteria like adsorption characteristics and physical properties are important. These data can be received from laboratory-, full scale or pilot plant studies. Some information is given by the supplier as a product specification. In particular physical parameters and behaviour during operation result only from practical applications.

In a research project [2] it was found that coal based GAC from Asia and from US differ in the parameter bulk density packed. Although the product specifications list similar values for the bulk density after backwashing, different values are found during the operation of a pilot plant. In a filter column the GAC from Asia is not that homogenous in bulk density after backwashing depending on the bed depth the carbon samples were taken. Such an impact of bed depth could not be observed for GAC from US. The range of values for the bulk density is 440 to 470 kg/ m³ (product specification: 460 kg/ m³) for US GAC and e.g. 340 to 550 kg/ m³ (product specification: 480 kg/ m³) for Asia GAC. The carbons are similar in the average values and the product specifications for the bulk density but differ in the range of bulk density considering the complete carbon charge.

From the results mentioned above it is supposed that the range of density may have an impact on backwash characteristics. Data for the backwash behaviour are not available for all carbon types especially new ones and due to the similar average values for bulk density it is not in evidence that the backwash procedure has to be changed. Thus a loss of GAC during the first backwash cycle can not be excluded if US GAC is changed by Asia GAC.
backwash characteristics are investigated in this project for actual Asia GAC types.

1.2 Characteristics of GAC from Asia (product specification)

For this research six different coal based GAC types produced in Asia are used. In comparison investigations with one GAC produced in US are done as well. The GAC types and some product specifications are listed in Table 1.

Table 1: Characteristics of the GAC – product specification

<table>
<thead>
<tr>
<th>GAC type</th>
<th>US-GAC</th>
<th>Hydraffin XC 30</th>
<th>GAC 830 W</th>
<th>DGF 0.5 - 2.5</th>
<th>Hydraffin Y 8x30</th>
<th>Hydraffin 30 N</th>
<th>S 835</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine number mg/g</td>
<td>920</td>
<td>1000±50</td>
<td>1000</td>
<td>1000±50</td>
<td>1000±50</td>
<td>1000±50</td>
<td></td>
</tr>
<tr>
<td>Nitrobenzene number mg/L</td>
<td>21</td>
<td>22</td>
<td>25</td>
<td>31</td>
<td>24</td>
<td>26</td>
<td>31</td>
</tr>
<tr>
<td>Density backwashed kg/m³</td>
<td>460</td>
<td>480</td>
<td>425</td>
<td>450±30</td>
<td>430</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*own measurement

1.3 Experimental Procedure

The backwash experiments are performed in a GAC pilot plant consisting of two filter columns as shown in figure 1.

Figure 1: GAC pilot plant for backwash experiments

The GAC (50 kg) is placed in a filter column. After a wetting time of 24 hours the GAC is slightly backwashed. As the carbon fines are removed and the
water is clear the backwash rate is increased stepwise until the whole carbon layer was fluidized. The bed expansion was determined for every given filter velocity. The bed expansion depends on the temperature due to the changing viscosity of the water. For all experiments the water temperature was 10 °C.

When the GAC layer was fluidized the filter velocity was reduced in five steps to achieve the optimal classing of the GAC. For further characterizing the GAC, carbon samples are taken from different filter depths (50 cm, 100 cm, 150 cm). For selected carbon samples additional investigations are conducted: GAC size distribution, bulk density and adsorption characteristics as iodine number and nitrobenzene number. The determination of the particle size distribution, bulk density and iodine number were carried out according to DIN EN 12902 [3]. The nitrobenzene number is developed in TZW and reflects the carbon demand for the removal of nitrobenzene under standardized conditions [4]. The higher the nitrobenzene number, the lower the adsorption capacity of the GAC.

1.4 Results

Backwash curves

The results of the backwash experiments are summarized in figure 2. As usual the bed expansion is plotted against the backwash velocity for the different GAC types. The black points reflect the expansion behaviour of a conventional coal based GAC (US).

Figure 2: Backwash curves for different GAC types (T = 10 °C)

The different coal based GAC types show a different backwash behaviour as can be seen from figure 2. However it is evident that the GAC types from Asia do not behave in the same way. Whereas the backwash curves of the
Asia GAC CarboTech DGF 0.5 - 2.5 and the US GAC are similar, the GAC types S 835 and Hydraffin Y 8x30 expand significantly more at a given backwash rate.

Some GAC types show an almost linear correlation between backwash velocity and bed expansion. Especially for S 835 and Hydraffin Y 8x30 the backwash curves are comparatively steep. The backwash procedure for these GAC types has to be performed carefully.

GAC fixed bed adsorbers are usually designed that a bed expansion of 30 % can occur. An 30 %-expansion is recommended for the removal of carbon fines and to avoid an initial head loss. Using GAC US a backwash rate of about 35 m/h is required as can be seen in figure 2. Depending on the GAC type backwash rates between 25 and 55 m/h have to be adjusted for an optimal backwash procedure.

Assumed that in a water utility the backwash regime is optimised for the GAC US it can be concluded that a backwash rate of 35 m/h will result in a bed expansion between 20 and 55 % depending on the GAC type. For the practical application the freeboard of the adsorber must be planned to more than 50 % according to these results otherwise a loss of material can not be prevented. In opposite GAC as GAC 830 W, Hydraffin XC 30 are not fluidized at a backwash rate of 35 m/h and an complete removal of carbon fines and an optimal placing of the GAC is not guaranteed.

The backwash curve do not give all information about the backwash behaviour. For an optimal backwash regime it is important that all the carbon grains are fluidized. It could be observed that for some GAC types the carbon grains from the bottom of the column are only fluidized at high backwash rates of about 50 m/h. Figure 3 shows the backwash velocity for achieving fluidization, whereas the Asia GAC types are listed in an order of increasing backwash rates.
The backwash rates for fluidization vary from 25 to 50 m/h. This parameter does not correspond to the bed expansion at a backwash velocity of 35 m/h as can be seen from figure 4. The GAC types are listed in the same order as in figure 3.

For three of the six Asia GAC types only a bed expansion between 20 and 25 % can be achieved at a backwash rate of 35 m/h. For the GAC 830 W such a backwash rate is not sufficient for fluidizing the GAC as can be seen from the figures 3 and 4. In opposite to this for the other three Asia GAC types the carbon bed expands much more to 40 to 60 %.

These results show that the backwash regime cannot be transferred from one GAC type to another. Even coal based GAC types with similar bulk densities give different backwash curves. If the backwash process is automated, as often done, a carbon loss may occur during backwashing.

More parameters for characterization of GAC are done for selected GAC types.

**Bulk density**
For some GAC types carbon samples were taken from different filter depths after the backwash procedure and the bulk densities were determined. As expected the bulk density is the lowest at the top of the filter layer (50 cm) and increases with increasing bed depth as can be seen from figure 5. For the US GAC the values for the bulk densities are between 440 and 510 kg/ m³ and so the extreme values do not differ a lot. But e.g. for the GAC Hydraffin XC 30 the bulk density in the upper layer is about 320 kg/ m³ compared to 570 kg/ m³ at the bottom. Differences in bulk density in such a dimension are not observed for the conventional US GAC so far.
The further Asia GAC types show bulk density ranges between 320 kg/m³ and 520 kg/m³. Comparing US GAC the these Asia GAC shows a lower bulk density of the Asia GAC especially in the upper layer.

In spite of this wide density range the average density of US GAC and the Hydaffin XC 30 are nearly the same as well as the bed expansion at a backwash rate of 35 m/h as shown in figure 4. For most GAC types lower values for the average bulk density are found in these experiments compared to the product specification as can be seen from table 2. A correlation between bulk density and bed expansion can not be derived from the experimental data as well.

Table: 2: Bulk density of different coal based GAC- product specification and average value from experiments

<table>
<thead>
<tr>
<th>GAC type</th>
<th>US-GAC</th>
<th>DGF 0.5 - 2.5</th>
<th>S 835</th>
<th>Hydraffin XC 30</th>
<th>Hydaffin 30 N</th>
<th>GAC 830 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>bulk density kg/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>product specification</td>
<td>460</td>
<td>440</td>
<td>480</td>
<td>430</td>
<td>425</td>
<td></td>
</tr>
<tr>
<td>experiment</td>
<td>475</td>
<td>390</td>
<td>405</td>
<td>450</td>
<td>410</td>
<td>425</td>
</tr>
</tbody>
</table>

Particle size distribution
For some GAC types the particle size distributions from the GAC samples of the different bed depths after backwashing were determined and are shown in the figures 6 to 11.

The particle size distributions for one GAC type is different in the three bed depths. As expected the curves for most of the GAC types are shifted to higher particle sizes with increasing bed depth. Exceptions are the GAC S 835 and Hydaffin 30 N which show the same particle size distribution in 100 cm
and 150 cm bed depth, and the DGF 0.5 - 2.5 with similar curves in bed depths of 50 cm and 100 cm.

Figure 6: Particle-size distribution of GAC US in different filter bed depths

Figure 7: Particle-size distribution of DGF 0.5 - 2.5 in different filter bed depths
Figure 8: Particle-size distribution of S 835 in different filter bed depths

Figure 9: Particle-size distribution of Hydraffin XC 30 in different filter bed depths
Figure 10: Particle-size distribution of GAC 830 W in different filter bed depths

Figure 11: Particle-size distribution of Hydraffin 30 N in different filter bed depths
To specify the size of the GAC the $D_{50}$ values can be expressed as done in figure 12 and table 3 for the GAC types in dependency of the filter bed depth. The $D_{50}$ value gives the size opening of the sieve that will just be passed by 50 mass % of the GAC.

![Figure 12: $D_{50}$-values of different GAC in three bed depths](image)

The GAC types US GAC, GAC 830 W and Hydraffin XC 30 show similar $D_{50}$-values in the three bed depths. However these carbon significantly differ in backwash characteristics. In addition Hydraffin 30 N and GAC 830 W show similar backwash curves but differ in $D_{50}$-values.

From the experiments it can be concluded that the mechanical properties of GAC e.g. backwash procedure can not be predicted from physical parameters as bulk density or particle size distribution.

### Table 3: $D_{50}$ values for different GAC types in different bed depths

<table>
<thead>
<tr>
<th>GAC type</th>
<th>US-GAC</th>
<th>DGF 0.5 - 2.5</th>
<th>S 835</th>
<th>HydraffinXC 30</th>
<th>Hydraffin 30 N</th>
<th>GAC 830 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{50}$ mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 cm</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.8</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>100 cm</td>
<td>1.6</td>
<td>0.9</td>
<td>1.3</td>
<td>1.4</td>
<td>1.8</td>
<td>1.6</td>
</tr>
<tr>
<td>150 cm</td>
<td>1.9</td>
<td>1.5</td>
<td>1.3</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
</tbody>
</table>

### Adsorption characteristics

To characterise the adsorption characteristics of GAC the Iodine number and nitrobenzene number are used. The iodine number is often used to survey the activation process. Another parameter which is more significant if a GAC was wetted before is the nitrobenzene number, which was developed in TZW [4]. The nitrobenzene number represents the carbon demand which is required under standardized conditions for the removal of nitrobenzene. Thus a higher nitrobenzene number means a lower adsorption capacity.
In table 4 all adsorption data are summarized for the GAC types after backwashing in the different filter bed depths. As shown in [4] the iodine and nitrobenzene numbers do not correspond over the carbon layer.

Table 4: Iodine and nitrobenzene numbers in different bed depths

<table>
<thead>
<tr>
<th>GAC type</th>
<th>50 cm</th>
<th>100 cm</th>
<th>150 cm</th>
<th>50 cm</th>
<th>100 cm</th>
<th>150 cm</th>
<th>50 cm</th>
<th>100 cm</th>
<th>150 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>US-GAC</td>
<td>Iodine number in mg/g</td>
<td>Nitrobenzene number in mg/L</td>
<td>Iodine number in mg/g</td>
<td>Nitrobenzene number in mg/L</td>
<td>Iodine number in mg/g</td>
<td>Nitrobenzene number in mg/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>900</td>
<td>1100</td>
<td>2400</td>
<td>31</td>
<td>31</td>
<td>31</td>
<td>900</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>DGF 0.5 - 2.5</td>
<td>835</td>
<td>840</td>
<td>850</td>
<td>900</td>
<td>900</td>
<td>900</td>
<td>950</td>
<td>990</td>
<td>990</td>
</tr>
<tr>
<td>S 835</td>
<td>700</td>
<td>710</td>
<td>720</td>
<td>900</td>
<td>900</td>
<td>900</td>
<td>990</td>
<td>990</td>
<td>990</td>
</tr>
<tr>
<td>HydraffinXC 30</td>
<td>500</td>
<td>510</td>
<td>520</td>
<td>900</td>
<td>900</td>
<td>900</td>
<td>990</td>
<td>990</td>
<td>990</td>
</tr>
<tr>
<td>N 830 W</td>
<td>400</td>
<td>410</td>
<td>420</td>
<td>900</td>
<td>900</td>
<td>900</td>
<td>990</td>
<td>990</td>
<td>990</td>
</tr>
<tr>
<td>GAC 830 W</td>
<td>300</td>
<td>310</td>
<td>320</td>
<td>900</td>
<td>900</td>
<td>900</td>
<td>990</td>
<td>990</td>
<td>990</td>
</tr>
</tbody>
</table>

While the nitrobenzene numbers after backwashing are almost independent of the bed depth for the US GAC, for some Asia GAC the nitrobenzene number is the highest at the top of the layer which means a lower adsorption capacity as can be seen from figure 12. This effect is unusual and for conventional US GAC the highest capacity is found at the top of the layer.

As found for other parameters as bulk density and particle size the Asia GAC are more inhomogeneous in adsorption capacity as well within one carbon charge. The impact on backwash characteristics can not be derived from these data.
1.5 Literature


