MULTI ReUse

Activated carbon filtration in wastewater treatment for water reuse

Activated carbon adsorption means the accumulation of molecules from the water at the surface of the activated carbon. This process is more effective if the affinity of the substance is higher to the adsorption properties of the activated carbon than to the dissolved form in water. Activated carbon has a highly porous capillary system so the surface of seven gram of activated carbon is equivalent to the size of a football pitch.

Activated carbon is used during the drinking- and wastewater treatment to remove organic micro pollutants (pharmaceutical, industrial- and household chemicals) among other things. Conventional mechanical biological wastewater treatment plants only remove few micro pollutants, the majority of them are brought into the aquatic environment again. To lower those numbers, more and more wastewater treatment plants have begun to use procedures to eliminate micro pollutants and for more than ten years activated carbon is successfully used for this purpose in Germany, the Netherlands, Austria and Switzerland (Kompetenzzentrum Mikroschadstoffe.NRW).

Objectives of process water treatment

If the effluent of local wastewater treatment plants is going to be reused for agricultural purposes, a barrier for micro pollutants is helping to reduce their release into the environment. A treatment with activated carbon is suitable for this purpose. Furthermore, a bed of granulated activated carbon has a very large grain surface and is a carrier material for microorganisms. Therefore it also is suitable for biological degradation processes (e. g. nitrification, denitrification, reduction of carbon compounds), which in return enhances the microbiological stability of the process water.

Figure 1: Discolouration with activated carbon (Source: IWW)

Assembly of carbon filters

The grain sizes of the granulated activated carbon used within water treatment procedures is usually between 0.6 und 2.36 mm. They are used as fixed beds in filters and can be built in an open form (e. g. as concrete chambers or -cells, see Figure 3) or in a closed boiler form (so called pressure filters that allow a filtration with a higher pressure loss). Filter boilers made of steel have to be furnished with a rubber coating on the inside to protect the walls against corrosion. Concrete filters usually don't need a coating like that. Further advantages may come from the large filter surfaces of

each filter chamber, the integration of concrete reservoirs and gutters for the raw water feed, filtrate discharge, flush water discharge as well as filtrate- and flush water stockage. All of this in one construction requires only little specific space and low investment costs.

Operation of activated carbon filters

Activated carbon filter usually are filled with granulated activated carbon up to dumping heights of 2–3 meters, thereby the coal is lying on a filter ground with nozzles. Depending on the application the filters are operated with filter velocities between 5 and 15 m/h. Here the lower range of 5 to 8 m/h usually is established for the wastewater treatment.

For the adsorption process however the empty bed contact time (EBCT) is more important (Benstöm et al. 2006a). This is a purely mathematical retention time for water in an empty bed without GAC, where times between 20–30 minutes haven proven to be appropriate (Benstöm et al. 2006b). This is calculated as a ratio between bed height and filter velocity (in m/min).

Figure 2: Granulated activated carbon (GAC) (Source: IWW)

If the water contains turbidity, the depositions in the GAC bed as well as the developing biological film lead to an increased pressure loss, which is why the filter needs to be flushed periodically. For this purpose air and water are used (separately) opposite to the direction of the filtration flow.

The GAC can be removed, thermally reactivated and reinstalled when it is charged with so many micro pollutants and DOC after a long use that it can't fulfil its purpose any longer. Practice showed that the use of reactivated GAC in wastewater treatment under ideal conditions doesn't show any performance losses, compared with the use of new GAC.

Resulting from this is the following sequence of working steps for the operation of single filters of a GAC stage (Kompetenzzentrum Mikroschadstoffe.NRW):

- First implementation of GAC in the filter (Adsorber)
- 10–24 months operation- resp. service life (depending on processed filtrate volume)
- Expansion of the GAC and transport to the service provider for reactivation
- Reactivation of the GAC in the oven with thermal degradation of micro pollutants
- Removal of undersize by sieving
- Replacement of fresh GAC making up for the quantity loss (so called make-up)
- Transport to the wastewater treatment plant, the filling of the filters, start of the next operation cycle

Pre- and follow-up treatment

Generally a well running wastewater treatment plant with a low content of DOC, resp. COD in the discharge is the best condition for the efficient elimination of micro pollutants. For a filter bed with GAC avoid water with high particle load, because a higher flushing frequency (mechanical stress) and the blocking of adsorption sites will result in a shorter operation time. In the MULTI-ReUse pilot plant, a pre-treatment by flocculation and ultrafiltration is being carried out. Here all suspended particles and a part of the DOC are removed, which is a good condition for a long operation time of the activated carbon. Hereby the flush intervals could be reduced to a maximum of two times a month.

Since a slight increase of manganese concentrations could be temporarily measured in the feed of the MULTI-ReUse pilot plant in Nordenham, an additional manganese removal filter had to be installed. The filter material serves as surface material for manganese oxidizing microorganisms who in combination with oxygen remove manganese through biologic catalysis.

The microorganisms absorb manganese (II) and release insoluble manganese (IV)-compounds as oxidation by-product. If this activity would take place in the activated carbon filters, their performance would be

Figure 3: Open GAC-filter at the wastewater treatment plant Obere Lutter (Source: AOL)

affected heavily because of the manganese coating. A sufficient microbial population for a complete manganese removal at a new filter usually needs a few weeks. To speed this process up, already microbial populated sand from a different filter can be used. A follow-up treatment with UV-disinfection guarantees microbiological stability and a hygienically acceptable operation of the activated carbon filter.

Monitoring

The monitoring of the GAC filters is carried out via analyses of selected indicator substances within the GAC influent and filtrate. They are selected because they are relevant for the location and represent a broad range of substance properties and sources (medical substances, industry and household chemicals, pesticides, etc). The use of UV extinction at 254 nm hasn't proven to be successful for the GAC filtration – in contrast to powdered carbon application.

Literature

Kompetenzzentrum Mikroschadstoffe.NRW (2018): Einsatz von Aktivkohle zur Wasser /Abwasserbehandlung, Broschüre, www.masterplan-wasser.nrw.de/downloads/broschuere-aktivkohle/

Benstöm F., Nahrstedt A., Böhler, M., Knopp, G., Montag, D., Siegrist, H., Pinnekamp, J. (2006a): Leistungsfähigkeit granulierter Aktivkohle zur Entfernung organischer Spurenstoffe aus Abläufen kommunaler Kläranlagen – Ein Überblick über halb- und großtechnische Untersuchungen. Teil 1: Veranlassung, Zielsetzung und Grundlagen. KA (63) Nr. 3, S. 187–192

Benstöm F., Nahrstedt A., Böhler M., Knopp G., Montag D., Siegrist H., Pinnekamp J. (2006b): Leistungsfähigkeit granulierter Aktivkohle zur Entfernung organischer Spurenstoffe aus Abläufen kommunaler Kläranlagen – Ein Überblick über halb- und großtechnische Untersuchungen. Teil 2: Methoden, Ergebnisse und Ausblick. KA (63) Nr. 4, S. 276–289

Authors

Dr. Andreas Nahrstedt and Anja Rohn
IWW Water Centre, Mülheim an der Ruhr

Contact: a.rohn@iww-online.de

Short description of the MULTI-ReUse project

Treated wastewater is an important part of the water cycle. It usually is fed into rivers, something that is acceptable from an environmental point of view but for the use in agriculture or industry the water often is unsuitable. MULTI-ReUse closes this gap by developing and implementing of new procedures for the reuse of service water. The aim of MULTI-ReUse therefore is the development, demonstration and evaluation of a modular water treatment system, in order to offer service water in different qualities and quantities for the different purposes and to competitive prices.

Imprint

This factsheet was produced within the research project MULTI-ReUse, funded by the Federal Ministry of Education and Research (BMBF) under the number 02WAV1403 and within the WavE support measure.

IWW Rheinisch-Westfälisches Institut für Wasserforschung gemeinnützige GmbH
Moritzstr. 26
45476 Mülheim an der Ruhr
Germany

Website: https://water-multi-reuse.org/
E-Mail: info@iww-online.de

Legally responsible:
Dr.-Ing. Wolf Merkel (Chief Technical Officer)

November 2018

SPONSORED BY THE
Federal Ministry of Education and Research
FONA Sustainable Water Management BMBF