Control of Adsorption with Powdered Activated Carbon

Micropollutants removal: Control of adsorption with PAC at Kressbronn-Langenargen WWTP

Problem

The Kressbronn-Langenargen Wastewater Treatment Plan (WWTP) has to ensure a stable operation through continuous monitoring and control of the powdered activated carbon (PAC) process while meeting the indispensable requirement to permanently guarantee the micropollutant elimination rate of 80%. Therefore, instrumentation is needed for monitoring and control. Currently, the rate of carbon and precipitants addition is set based on the flow and not on the actual load.

Solution

To continuously monitor the efficiency of micropollutants elimination the customer could measure the established parameter Spectral Absorption Coefficient (SAC254) in the inlet and outlet of the adsorption treatment process as it correlates with the elimination rate of micropollutants. This parameter can be used to control the PAC-dosage. In addition, measurements of Total suspended solids (TSS), turbidity and sludge level will ensure the efficiency of the process.

Benefits

With adoption of the tested solution the process can be optimised on dosing of precipitants and PAC according to the dynamic incoming concentration of micropollutants to meet the targeted elimination rate. By monitoring TSS and Turbidity, loss of activated carbon can be prevented and a balanced amount of PAC in the system can be assured.

Background

The Wastewater association of Kressbronn-Langenargen has operated their municipal wastewater plant in the South of Germany since 1967. The plant discharges into Lake Constance, which also serves drinking water purposes, therefore preventive protection of the water quality is a concern. In order to selectively reduce the concentration of micropollutants, such as pharmaceuticals, in the effluent of the Kressbronn-Langenargen WWTP, in July 2011 the plant was upgraded with an adsorption treatment stage using powdered activated carbon (PAC). The elimination of micropollutants not only protects health and drinking water sources but also improves the quality of the aquatic environment and minimises the ecotoxicological effect, such as estrogen presence on fish, algae and other aquatic life.

Kressbronn-Langenargen WWTP

The Kressbronn-Langenargen WWTP is designed for 24,000 PE (Population Equivalent) and treats a wastewater volume of 2,300,000 m^3/year. The plant manages a maximum of 252 L/s of combined sewage flow. The wastewater undergoes the mechanical treatment, then the biological treatment with a one-stage aeration phase and clarification followed by sand filtration.

Table 1: Key Data of Kressbronn-Langenargen WWTP

WWTP size	24,000 PE
WW volume	2,300,000 m^3/year
Mixed water flow	252 L/s

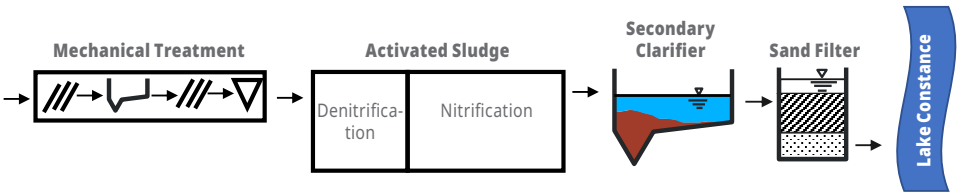


Figure 1: Schematic process of Kressbronn-Langenargen WWTP until 2011

Implementation of the adsorption stage

The adsorption stage was newly constructed in 2011 and hydraulically connected after the clarifier past the biological treatment stage. The effluent of the adsorption stage goes to the existing sand filter. This single channel adsorption stage consists of a contact reactor with three basins in a row and a circular downstream sedimentation tank. To operate the whole adsorption process, instrumentation is needed to monitor and control relevant parameters in order to reach the target elimination rate. This systematic elimination of micropollutants with a downstream stage by PAC is also called the "Ulmer-Verfahren". The elimination rate of micropollutants that has to be achieved by the WWTP is 80%.

Since implementing the adsorption stage an improved P-elimination could be seen without increasing the addition of precipitants.



Figure 2: Sedimentation tank at Kressbronn-Langenargen WWTP



Figure 3: Contact reactor of the adsorption stage

Operation of the adsorption stage contact reactor

The main additive in the adsorption stage is powdered activated carbon to adsorb the micropollutants out of the wastewater. This stage is designed to treat a continuous flow up to 265 L/s. In the first basin of the contact reactor, fresh powdered activated carbon is added proportional to the flow rate and return flow carbon inserts. There are stirrers in each of the three basins mix that the biologically treated wastewater with the carbon and also maintain the suspension in abeyance. The contact time between activated carbon and wastewater amounts to at least 35 minutes. An adequate treatment to reach that performance requires 7 mg PAC/L with dosing controlled by flow.

In the next step, the activated carbon sludge needs to be separated from the treated water again. With the dosing of precipitants and flocculants/polymer, ideal flake structures and sizes will be generated to improve the settling characteristics of the activated carbon in order to ensure sufficient retention. The dosing is conducted equivalent to either PAC or the flow rate in an overflow weir which is located at the outlet area of the third contact reactor. Excess carbon will be pulled back into the aeration tank. Figure 4 shows the schematic process and the locations of the monitoring points for the SAC254 measurement as well as the other relevant parameters.

Sedimentation Tank

The addition of precipitants and also flocculants is mandatory before the activated carbon sludge reaches the sedimentation tank in which the solids have a minimum of 2.6 hours to settle to the bottom of the tank. The settled carbon sludge returns to the contact reactor while the excess sludge will be pulled back to the biological treatment stage so it can be discharged with the sludge. The water passes another stage of precipitation before reaching the sand filter.

Sand Filter

To separate the fine fraction of activated carbon, the treated water enters the last treatment stage with filtration which already exists in Kressbronn. This filter unit can prevent activated carbon of leaving the wastewater treatment plant (PAC loss).

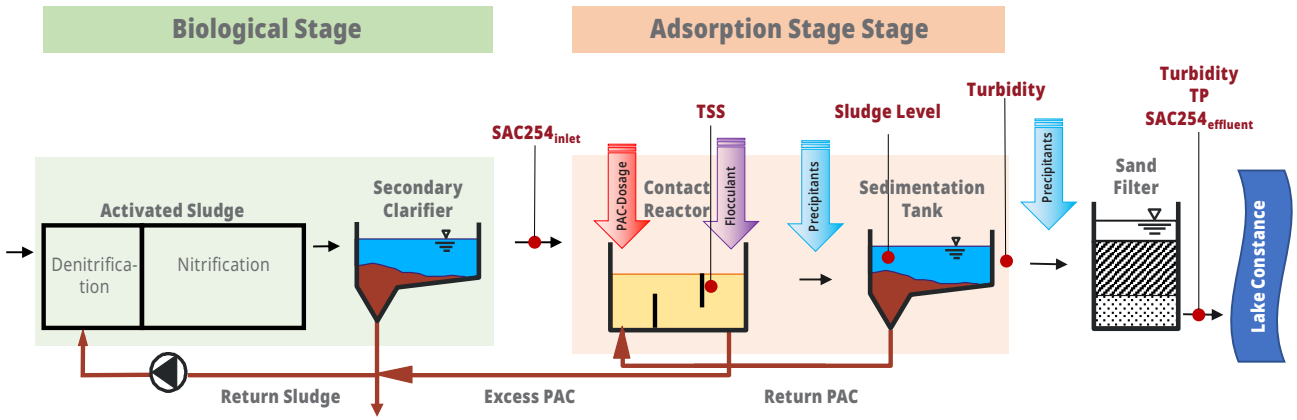


Figure 4: Parameter monitoring in the adsorption process at Kressbronn-Langenargen WWTP

Table 2: Key data of the adsorption stage

Qmax in PAC stage	265 L/s
Contact reactor size	552 m³
Min. retention time in contact reactor	35 minutes
Sedimentation tank size	2540 m³
Min. retention time in sedimentation tank	2.6 h
Surface charge in sedimentation tank	1.6 m/h

Table 3: Dosage data

First basin of contact reactor	PAC	~7 mg PAC/L
Effluent of 3rd basin of contact reactor	Precipitant	~5.6 mg Fe/L
Effluent of 3rd basin of contact reactor	Flocculant	~0.26 mg/L
Effluent of sedimentation tank	Precipitant	0.5 – 1.5 Fe mg/L

Process monitoring with SAC254

The reduction in the Spectral Absorption Coefficient (SAC 254 nm) correlates with the removal rate of organic substances, hence micropollutants, in wastewater. Therefore, this coefficient can be applied as a sum parameter for micropollutants and is suited to monitor the reduction of the indicator substances and the treatment efficiency of the PAC-stage. Experience has shown that with an effective SAC254 reduction by 40%, an average removal of 80% of indicator substances can be achieved during the PAC adsorption process[1].

Kressbronn-Langenargen WWTP has applied one UVAS probe in the effluent of the clarifier from the biological step and another one in the effluent of the sand filter to measure SAC254. The measurement points can be seen in Figure 4. These probes have been installed since 2011 and are still operating with little maintenance. The instrumentation is connected to the SC1000 controller which can show measurement data and curves of each parameter in real-time. Another measuring method considered by the WWTP is to use DR6000 to measure the absorption coefficient in the laboratory as a reference value. Figure 5 shows recorded data of the online measured SAC254 by the two UVAS-probes and the resulting ΔSAC254. It can be seen that the elimination rate drops to 20% a few times in the recorded period. Those events correlated with rainfall.

[1]*Roessler et al. (2016): Application of SAC254 measurement for the assessment of micropollutant removal in the adsorptive treatment stage of a municipal wastewater treatment plant*

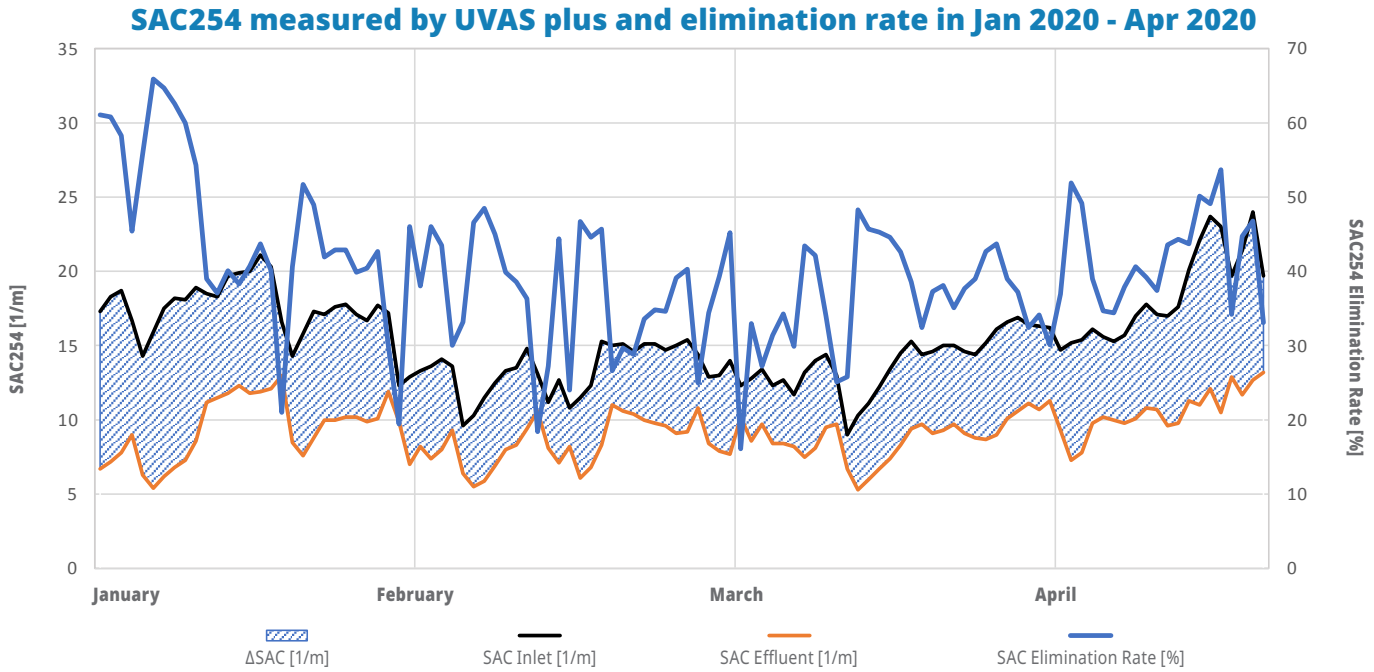


Figure 5: Online measurement of SAC254 by UVAS plus at Kressbronn-Langenargen WWTP during January 2020 and April 2020

Control of PAC balance in the adsorption stage

A Solitax for TSS is implemented in the third tank of the contact reactor. If TSS reaches 4.5 g/L the excess PAC will be discharged. The maximum discharge amount of PAC is 30 m^3/d. This is how the PAC balance in the contact reactor is kept. A Sonatax in the sedimentation tank has the purpose to track the sludge level. With the Solitax, turbidity in the filter effluent and solids can be monitored or PAC that could leave the filter can be tracked.

TP measurement in the effluent

Since Kressbronn-Langenargen WWTP has upgraded their plant with the adsorption stage an enhanced P-removal occurred. Total Phosphorus (TP) of 0.02 mg/L in the effluent can be reached which meets the current compliances and is well-positioned for future demands. A Phosphax Sigma is installed to monitor Total Phosphorus (TP) and Ortho-Phosphate (Ortho-P) in the effluent.

Outlook

Currently, the plant operates the dosing of PAC and precipitants relative to the flow. As the hydraulic situation fluctuates due to dry and wet weather flow, the dosing of PAC and precipitants is not accurately adjusted to the concentration of incoming organics. Kressbronn-Langenargen WWTP not only continues to use UVAS to monitor the elimination rate of SAC254 but also plans to utilise the reliable and real-time data generated by UVAS to adjust the dosing of PAC and precipitants. 40% of ΔSAC254 will be targeted for the settings.

Considerations

In order to protect sensitive water bodies from pollution wastewater treatment plants should be upgraded with the adsorptive treatment step to prevent the discharge of organic micropollutants. With the construction of a completely new treatment stage using powdered activated carbon at the Kressbronn-Langenargen WWTP in 2011, new challenges with monitoring and control came up. To understand the processes within this treatment stage, Hach provided instrumentation for monitoring and control from the point of influent to the effluent.

As the reduction rate of SAC254 correlates with the elimination rate of micropollutants, online monitoring of this parameter with UVAS plus provides the customer with the real-time information about the efficiency of the adsorption and if the target is achieved. Therefore, this customer plans to use SAC254 to fit the operation to the dynamic load in the PAC process in the future. Measuring TSS with Solitax helps the customer to keep the PAC concentration balanced in the treatment cycle. The Solitax for Turbidity is applied in the effluent of the sedimentation tank and of the sand filter to detect any PAC loss. The improved performance of the Phosphorus reduction could be tracked by Phosphax Sigma.

The customer at the Kressbronn-Langenargen WWTP operates this adsorption stage with using the reliable solution from Hach from the beginning since 2011 and it has proved to be a beneficial tool for process monitoring and control. The high quality of the instrumentation could hold out against the abrasive characteristics of activated carbon and requires low maintenance.

The Hach solution for controlling adsorption with powdered activated carbon is implemented not only at Kressbronn-Langenargen WWTP but also at several other wastewater treatment plants in Germany and Switzerland and can also be applied for monitoring and control of adsorption with granular activated carbon as well as ozonation.

Summary of Applications

Application	Parameter	Measuring point	Instrument
Monitoring of elimination rate and control of PAC-dosage	SAC254	Influent of PAC-stage and Effluent of filter	UVAS plus sc
Laboratory verification of SAC254 Online measurement	SAC254	Influent of PAC-stage and Effluent of filter	DR6000
Monitoring TSS and control of sludge concentration in contact reactor	TSS	Contact reactor	Solitax
Monitoring PAC loss, wastewater quality changes and filter breakthrough	Turbidity	Effluent of sedimentation tank and filter	Solitax
Monitoring sludge level and control sludge discharge	Sludge level	Sedimentation tank	Sonatax
Monitoring P to meet compliance	TP, ortho P	Effluent of filter	Phosphax Sigma

About the customer

Zweckverband Abwasserreinigung Kressbronn-Langenargen

Industry + Application: Municipal Wastewater; micropollutant removal with PAC

Region: Germany

Contact: E.-A. Müller

Position: Plant Operator



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