xylem
Let's Solve Water

Wastewater

Municipal Wastewater Treatment Plant
To make wastewater useable again or to discharge it into the environment, it has to cleaned in a multistage process of a wastewater treatment plant. There are three major cleaning steps, located between inlet and outlet of a plant: mechanical cleaning, biological cleaning, chemical cleaning. An additional part is the treatment of the sludge, which is produced during the cleaning. In all areas, process monitoring is required to take corrective action if needed. This monitoring can be ensured by measuring the respective parameters. The measuring location can be critical for proper monitoring.

Inlet
What parameters to measure at the inlet of a wwtp?

Hence, in the inlet and the within the mechanical cleaning (screen, sand trap, oil filter, etc.) an analysis of the incoming wastewater in necessary, to get initial concentrations of nutrients, organic or salt load. For this, optical probes with ultrasonic cleaning for sum parameters (e.g. SAC, COD, BOD) or sensors for specific parameters (e.g. pH, Cond) can be used. The optimization of the sludge extraction in the pre-clarifier (end of mechanical cleaning), can be reached by a sludge level measurement.

Biology, chemistry & cleaning
What is the working principle of the Biological cleaning?

The elimination of nitrogen – mainly chemically bounded in ammonium – happens through biochemical reactions. In aerobe conditions, ammonium is oxidized via nitrite to nitrate by nitrification. After recirculation into an anaerobe tank, nitrate is reduced to elementary nitrogen by denitrification. Hence, the described process takes place very often conversely to the structural arrangement of the tanks. This means that parts of the wastewater passing through twice. This so called activated sludge process requires the recirculation of produced nitrate from the aerobe into the anaerobe basin. Here, process monitoring concentrates on measuring ammonium (NH_4), nitrate (NO_3) and oxygen (O_2). For this, our stable ISE sensor and the calibration free oxygen sensor are advisable. The additional control of total suspended solids (TSS) within the activated sludge is helpful, as an optimal concentrations of solids leads to higher nitrification, denitrification and phosphate elimination. Besides our suspended solids sensor also the turbidity sensor can be used. Both sensors convince by an integrated automatic ultrasonic cleaning. To measure NO_3, TSS and carbon parameters like COD, we recommend our reagent free optical spectral probes.

What is Bio-P?
In case of an applicable biological phosphate elimination, a so called bio-P tank is located upstream of the biological cleaning tanks. Under anaerobe conditions, the phosphorus content is initially increased, as stressed bacteria release their stored phosphate. After transferring into an oxidized tank, bacteria take up more phosphate than they released before. This behavior is called „luxury uptake". Significant conditions for this process are not only a lack of oxygen, but also a lack of nitrate and the availability of easily degradable organic substrate.
For the entire process of biological cleaning, the respective oxygen concentrations are of vital importance. Hence, measuring this parameter by accurate oxygen sensors is indispensable. Again, in the final post-clarifier the sludge extraction can be controlled by a maintenance free sludge level measurement.

WTW
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How works chemical phosphate elimination?

The chemical cleaning is based on adding precipitants. To control the dosing of for example aluminum or iron concentration, the Ortho-phosphate remaining after the biological cleaning should be measured. Here, a PO_4 analyzer including filter plate is recommended. Even in case of a very efficient bio-P (see above), this chemical procedure is seen mostly, as Ortho-phosphate cannot be removed completely within the bio-P.

Sedimentation

The sedimentation of sewage sludge takes place at almost every sewage treatment plant in so-called primary and secondary sedimentation tanks. The mostly circular basins are located before and after the biological treatment stage. The sludge that settles is called primary sludge (primary clarifier) or secondary sludge (secondary clarifier). The primary sludge is clearly more inhomogeneous in its composition than the secondary sludge.

The settling sludge is removed by pumps at certain intervals or continuously. The primary sludge is completely fed into the sludge treatment. Some of the secondary sludge (= activated sludge) is pumped back into the biological treatment stage and the rest is returned to the sludge treatment together with the primary sludge as surplus sludge.

The sludge level can be monitored in both basins using the IFL 700 IQ sludge level sensor. The great advantage of this continuous monitoring is that, on the one hand, pump times can be reduced and, on the other hand, sludge run-off, which is very critical for the plant, can be prevented.

4th purification stage

Background

Surface and groundwater polluted with micropollutants have been increasingly in the public focus for some time. Micropollutants, also known as trace substances or micropollutants, are organic residues released by synthetic compounds. These include substances such as X-ray contrast media, medicines, hormones, pesticides as well as industrial chemicals, but also everyday products such as cosmetics and household chemicals.

Even though micropollutants can only be detected in water bodies in very low concentrations of ng/l or µg/l, some of these substances have been classified as potentially hazardous to water bodies or health. In water bodies, many micropollutants exceed the concentrations of the environmental quality standards prescribed by law in the EU Water Framework Directive. They are largely discharged into surface waters via sewage systems and wastewater treatment plants, as they cannot be sufficiently degraded by conventional wastewater treatment processes such as mechanical and biological treatment.

At wastewater treatment plants, the fourth treatment stage stands up to micropollutants

A new process stage, the so-called fourth treatment stage, is needed for the targeted and effective removal of micropollutants in wastewater treatment plants.

In Switzerland, a new water protection law came into force at the beginning of 2016, which prescribes the fourth treatment stage for large waste-water treatment plants (> 80,000 p.e.) or wastewater treatment plants at particularly polluted water bodies and is intended to contribute to the protection of water bodies and drinking water resources. Approximately 100 of the 700 Swiss wastewater treatment plants that will be equipped with a fourth treatment stage in the next 20 years are affected. In 2014, the Federal Environment Agency demanded in a position paper that a fourth treatment stage be introduced in Germany at wastewater treatment plants of size class 5 and smaller wastewater treatment plants that discharge into clean waters that are sensitive to pollution. However, a legal basis for the introduction of the fourth treatment stage, as in Switzerland, does not yet exist in Germany.

Currently, the federal states of North Rhine-Westphalia and Baden-Württemberg are taking a pioneering role in environmental protection and have each established their own competence centres (Kompetenzzentrum Mikroschadstoffe. NRW; KomS Kompetenzzentrum SpurenstoffeBW) for micropollutants. These carry out scienti-fic work as well as feasibility studies in coop-eration with operators and universities and accompany pilot projects as well as the large-scale implementation of the fourth treat-ment stage at sewage treatment plants. According to the current state of research, two processes are particularly well suited for the fourth treatment stage, also from an economic point of view: One is a so-called adsorptive process that uses activated carbon. The micropollutants accumulate on the activated carbon (adsorb), the polluted activated carbon is removed from the process and then incinerated. The other is ozonation, which is an oxidative process.

Activated carbon process

In this adsorption process, activated carbon is added to the wastewater. The micropollutants then accumulate on the large surface of the carbon particles through adsorption. The activated carbon is then filtered out and either recycled or disposed of. Depending on the particle size, a distinction is made between granulated (GAK) and powdered activated carbon (PAK). In most cases, the activated carbon is fed into the activated sludge tank. Depending on the structural possibilities of a wastewater treatment plant, however, there are also other procedures for PAH, e.g. with a separate reaction tank.

Ozonation

If ozonation is used as the fourth treatment stage, it is installed downstream of the mechanical-biological treatment processes. Ozone introduced into the water phase reacts with the micropollutants and, in the best case, converts them into non-toxic, degradable components. Typically, ozonation is followed by filtration. This filtration, often a biologically active filtration, serves on the one hand to convert the reaction products into biomass and on the other hand to remove any toxic reaction products that may occur from the wastewater. However, this process not only significantly reduces the concentrations of micropollutants, but also improves "classic" wastewater treatment plant parameters such as TSS, COD and colouring of the wastewater, which ultimately benefits the plant's discharge values.

Measurement technology for the 4th purification stage

Laboratory analysis to determine hundreds of different substances is very complex and expensive. Since micropollutants only occur in very low concentrations, they cannot currently be measured using continuous online measurement technology. However, with SAK, DOC or COD, suitable substitute parameters have been found that give an indication of the purification performance. The SAK (spectral absorption coefficient) is the most frequently used parameter, as DOC and COD involve more complex reference methods in the laboratory. SAK can thus be measured before and/or after filtration or ozonation and used as a control value.
Xylem offers a digital single parameter sensor for the IQ Sensor Net for this purpose. Accurate results and integrated ultrasonic cleaning thus enable reliable and low-maintenance process monitoring and control.

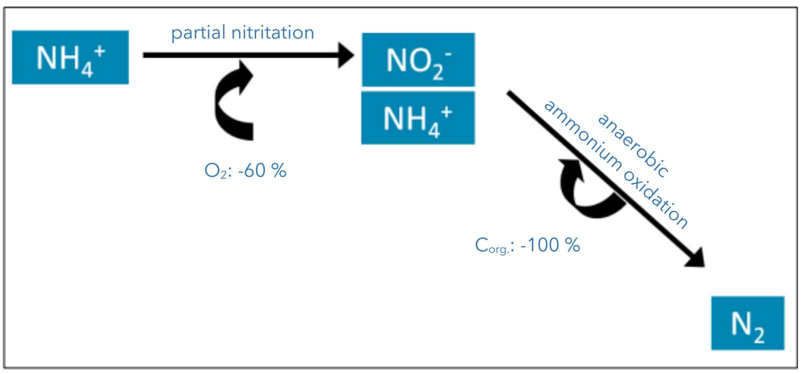

Fig. 1: Schematic representation of the deammonification, consisting of the two steps partial nitritation and anaerobic ammonium oxidation

Outlet

Which parameters need to be monitored at the outlet?

The cleaned water is discharged from the treatment plant into surface waters also called receiving waters. For this, official permissions are needed and outlet concentrations have to be met.
Despite regional or country specific differences, generally the following parameters have to be monitored: COD, BOD5, NH4-N, N_{tot} (NH4-N + NO2-N + NO3-N) and P_{tot}.
To determine these concentrations, measuring locations, sampling procedures, sampling preparations and analytical methods are defined.

Sludge treatment

Why to measure sludge level?

The treatment of the produced sludge happens in a separate process chain. Here, any raw sludge, which was not recirculated into the biological cleaning stage, is transformed into treated sewage sludge. Process steps are thickening, digestion and dewatering. To monitor the mass fluxes and the cleaning efficiency of the plant, a measurement of total suspended solids and turbidity in needed. As sensor cleaning is important, suspended solids sensors and turbidity sensor including a self-cleaning are recommended.

Deammonification (partial nitritation/ anaerobic ammonium oxidation)

In partial nitrification, about 50% of the ammonium present is degraded to nitrite. In the second step, deammonification bacteria come into play and convert the remaining part of the ammonium nitrogen and the nitrite formed into elemental nitrogen. Since the representatives of these bacteria are anaerobic, chemolitho-autotrophic microorganisms, they require neither oxygen nor organic carbon. The oxygen requirement is reduced by 60%. Carbon is not needed at all, the saving is 100% (Figure 1).

One and two-stage process

Deammonification can be operated as a one-stage or two-stage process. In the single-stage process, both process steps - partial nitritation and anaerobic ammonium oxidation (anammox) - are carried out in the same basin or tank. In the two-stage process, the two steps take place in separate tanks.

In the single-stage process, an oxygen setpoint of less than 0.5 mg/l is usually selected. This is to avoid excessive nitrite accumulation and the oxidation of nitrite to nitrate. The nitrite concentration here is 2 - 25 mg/l, as too high a concentration has an inhibitory effect on the anammox bacteria. Therefore, when the upper O_2 limit is reached, aeration is switched off. During the aeration phase, nitritation dominates, but anaerobic ammonium oxidation also takes place to a lesser extent.

In the two-stage process, on the other hand, oxygen setpoints of up to 1 mg/l are selected. Accordingly, higher nitrite concentrations (up to 750 mg/l) are possible. Both methods produce nitrate nitrogen in a concentration that is about 10% of the concentration of ammonium nitrogen.

Occurrence of deammonification

During the sludge treatment of a wastewater treatment plant, nitrogen-containing process water with very high ammonium concentrations accumulates (up to 2,000 mg/l ammonium possible). Existing systems can often only inadequately cope with these considerable loads. Attempts to force sufficient nitrification often fail and result in excessively high effluent nitrate levels. Ultimately, in such cases, new approaches to wastewater treatment have to be taken to cope with the increased loads from the process water.

Challenges of deammonification

A significant difficulty in the first large-scale deammonification plants was the very time-consuming concentration of the special microorganisms, which could take up to several years. Nowadays, with the availability of well established plants with sufficiently large biomass, this difficulty has been largely eliminated. The bacteria can now also be used in larger quantities from existing plants to inoculate new plants. The running-in times of new plants are now only a few weeks. Process stability has also increased due to several years of experience, optimised measurement and control concepts and reliable measurement technology.

The biological activity of the deammonification organisms is subject to certain influencing variables, knowledge of which is imperative for a smooth deammonification process. The nitrite required for anaerobic ammonium oxidation has an inhibitory or toxic effect on the bacteria in increased concentrations, which can result in irreversible damage to the entire process. Sulphur compounds and methanol have a similar effect. With regard to a single-stage process, the oxygen required for partial nitrification simultaneously leads to the inhibition (reversible) of the organisms. Anaerobic ammonium oxidation thus requires sufficiently long phases with very low oxygen concentrations.

Nitritation and anaerobic ammonium oxidation have an opposite effect on the pH value. Aeration only occurs within a very narrow pH interval. During this phase, nitritation dominates over anaerobic ammonium oxidation. The nitrite formed causes the pH value to drop until the lower threshold value (approx. at pH 7.00) is reached. The aeration is switched off, the O_2 concentration drops and the nitrite formed is used up to oxidise the ammonium still present (anaerobic ammonium oxidation). The pH value increases both through this process and through the continuous addition of alkaline process water up to the upper threshold value, which in turn leads to the start of aeration.

In addition, too low a temperature and too high a solids content lead to increased formation of NO_3. This in turn results in an inhibition of anaerobic ammonium oxidation.

Usable measurement technology

Besides the most common parameters pH and oxygen, monitoring and control variables also include nitrogen concentrations (NH_4-N, NO_3-N, NO_2-N), temperature and dry matter. Xylem offers suitable digital sensors for these parameters, all of which can be connected to the IQ Sensor Net measuring system.

pH: SensoLyt® 700 IQ
O_2: FDO® 700 IQ or TriOxmatic® 700 IQ
Nitrogens: ISE sensors, e.g. VARiON® 700 IQ
TS: ViSolid® 700 IQ
Temp: integrated in various sensors
System: IQ Sensor Net

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