Oxelia™ – Combined Oxidation and Biological Filtration Process for Tertiary Wastewater Treatment

INTRODUCTION

In Germany and Switzerland, there are currently discussions on the implementation of an additional treatment step at municipal wastewater treatment plants for the elimination of micropollutants. Water protection is foregrounded here, since already low concentrations of micropollutants give reason to assume danger to the aquatic environment. For minimizing this potential danger in the future, technical processes are required in order to remove or oxidize the substances. Activated carbon as well as ozonation are identified as appropriate processes [1][2]. Both processes are already under industrial implementation, have proved themselves in permanent operation and achieve comparable removing effectiveness for most micropollutants considered [3]. With regard to space requirements and control flexibility, ozonation turns out to be advantageous due to shorter response times required. Moreover, the ozone procedure scores with regard to effectiveness (costs) as well as the need for primary energy required as demonstrated in Table 1.

Table 1: Compilation of energy consumption and costs for post-ozonation or PAC-adsorption [4]

	Unit	Ozone	PAC
Additional energy consumption wastewater treatment plant	kWh/m³	0.05 – 0.15	> 0.005
Additional energy consumption wastewater treatment plant (incl. sand filter)	kWh/m³	0.1 – 0.2	0.05
Increase energy consumption wastewater treatment plant	%	20 – 50	10 – 20
Primary energy	kWh/m³	0.3 – 0.5	0.4 – 0.7
Costs small wastewater treatment plants < 15,000 PE	CHF/m³	0.32 – 0.36*	0.42 – 0.47*
Costs small wastewater treatment plants < 15,000 PE	CHF/PE/a	32 – 36	42 – 47
Costs large wastewater treatment plants > 100,000 PE	CHF/m³	0.09 – 0.11*	0.15 – 0.20
Costs large wastewater treatment plants > 100,000 PE	CHF/PE/a	10 - 15	15 - 20

**Average amount of wastewater per inhabitant: 100 m³ per annum*

During ozonation micropollutants are oxidized. This causes a change in the structure of the micropollutant and an elimination of undesirable effects giving distinction to the product (e.g. hormonal stimulation). This was confirmed by ecotoxicological examinations which moreover have not indicated any negative effects of secondary products and even revealed a positive ecotoxicological net balance [1][5]. It is advisable to further degrade potential secondary products of oxidation using a downstream filter. Apart from micropollutants, other parameters are changed by oxidation as well:

- The COD value is reduced by ozone oxidation.
- At the same time, the BOD_5 value is slightly increased. If the downstream filter is biologically active, this may induce a further reduction of the BOD_5.

Also those substances (e.g. secondary products) are degraded that are becoming biologically available by the ozone stage. Hence, the combination of ozonation and biologically active stage provides an effective protection of waters against emission of micropollutants. This idea was further developed by Xylem and consolidated in the Oxelia oxidation-enhanced biologically active filtration system.

Within an internal research project with a pilot plant the system described was thoroughly investigated with regard to cleaning efficiency and total costs [6].

OVERVIEW AND PROCESS STEPS

In 2012, Xylem installed a complete wastewater treatment plant on the site of the Hammarby Sjöstadsverket research and pilot plant, located on the site of the largest wastewater treatment plant of Stockholm (Henriksdal, Sweden) in order to test and being able to compare process combinations for different goals of treatment. Apart from experts of Xylem subsidiaries, operations and analytics were supported by the Swedish Environmental Research Institute (IVL).

Figure 1: Xylem pilot plant

For oxidation, a Wedeco ozone system was used. In this process, the gaseous ozone is introduced into a bubble column via ceramic diffusers in order to react with dissolved matter there. The ozone system was designed for dosages of up to a maximum of 16 mg ozone/L or 1.2 g ozone/g TOC at an average retention time of 20 minutes.

Downstream oxidation, Leopold filtration systems are installed. In parallel, they have been operated as biologically active filtration systems with an anthracite layer as well as a layer of granulated activated carbon.

All process parameters on this process combination were determined using various test probes of WTW. The selection of probes comprises the parameters pH, temperature, dissolved oxygen, turbidity, TSS, ammonium, nitrate, COD, UV-T, conductivity and redox potential.

The following figure reveals an overview of the procedures applied.

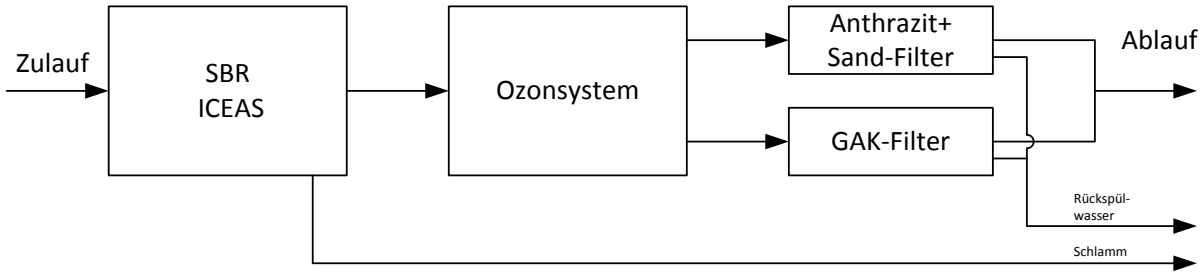

Figure 2: Block diagram of the procedures applied

The raw water serving for the experimental series is untreated municipal wastewater with an industrial proportion and a flow rate of 2 m³/h, taken in front of the Henriksdal wastewater treatment plant. Biological treatment is by a Xylem Sanitaire ICEAS® advanced SBR whose biologically treated water was transmitted into the ozone stage where it is treated with ozone and the wastewater oxygen-saturated due to oxidation after that sent via two filter columns operated in parallel (refer to Figure 2). One filter column was equipped with sand and anthracite, the second column with granulated activated carbon. After an optimization phase, the filters were operated with a contact time (EBCT) of 15 minutes. During the ozone tests, the ozone dosage was varied in order to investigate the consequences on the degradation of specific parameters. The specific parameters are TOC, COD, BOD_5, UV-T (transmittance at 254 nm), solid material and 26 different micropollutants.

RESULTS OF THE EXPERIMENTAL SERIES WITH THE COMBINATION OF OZONE AND FILTER

The impact of the combination of an ozone system and the two filter systems on the selected parameters is shown in the following Table 2.

Table 2: Impact of the combined ozone and filtration process on selected parameters (average values over three months)

Parameter	Unit	Influent ozone system	Effluent ozone system	Effluent anthracite filter	Effluent GAC-filter
TOC	mg/l	12.6	11.8	9.1	8.5
COD	mg/l	41.9	32.2	20.3	21.2
BOD_5	mg/l	7.3	8.0	3.0	2.7
UV-T	%	53.8	73.0	77.4	77.9
NH-4-N	mg/l		0.79	0.05	0.03
SS	mg/l		4.67	0.47	0.66

The combination of ozone and biologically active filter enables an advanced degradation of the specific parameters. The ozone stage involves a slight reduction of the COD and accordingly the TOC as well. This relates to the oxidation of dissolved matter and micropollutants converted and made bio-available by the effect of ozone. This is also demonstrated by the BOD_5 which is slightly increased after ozone stage. In the biologically active filters, the COD and also the BOD_5 are further reduced. Depending on the ozone dosage and the influent water quality, a degradation of the COD of up to 50% can be achieved. Moreover, the ozone stage involves a considerable improvement of the UV transmittance and eliminates the yellowing typical in wastewater. Due to filtration, the content of suspended substances (SS) remains constant below 2 mg/L and the nitrogen content features a considerable reduction as well.

Samples were taken and micropollutants analyzed by the IVL. All sum, 26 substances of the fields pharmaceuticals and industrial chemicals have been investigated. For the following analysis, only selected

substances (carbamazepine, sulfamethoxazole, ibuprofen, metoprolol and benzotriazole) are chosen as examples for different classes. The following figure reveals a logarithmic representation of the degradation of these substances.

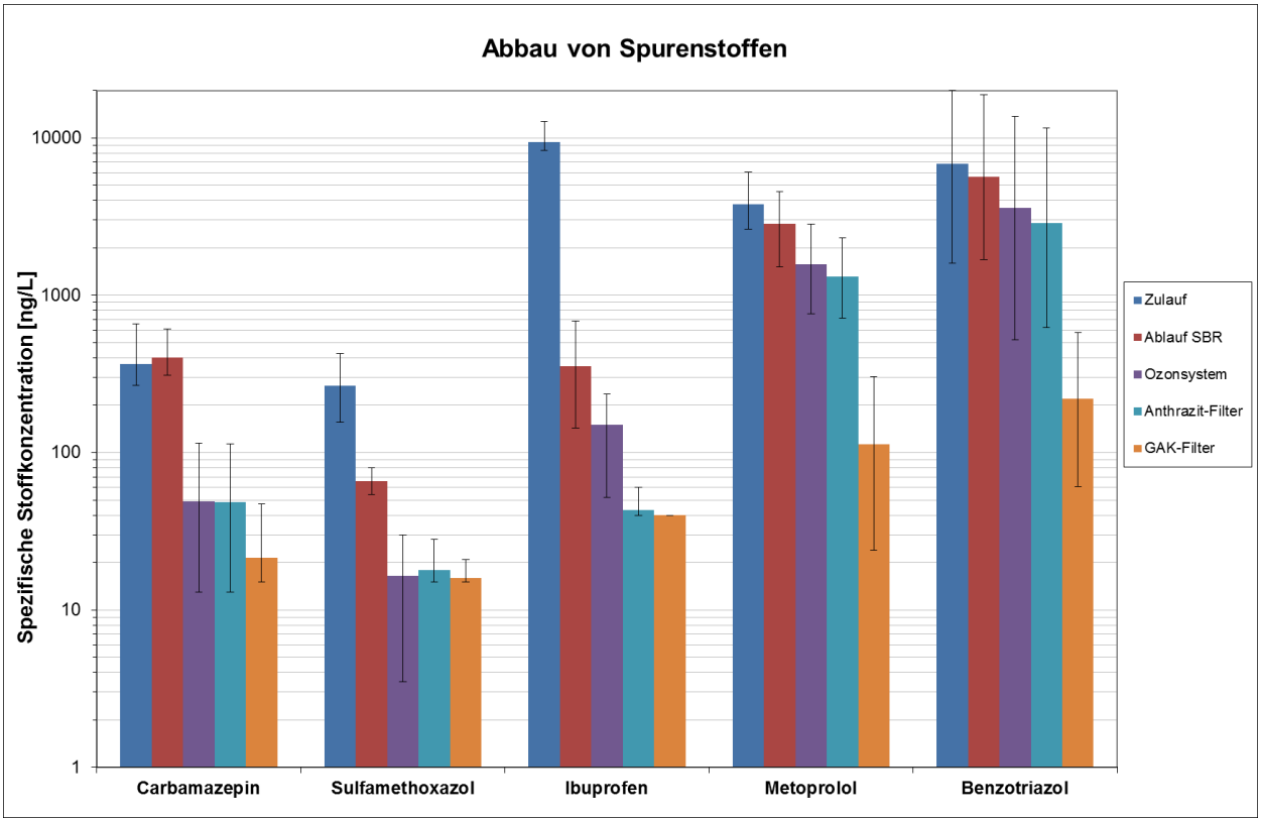

Figure 3: Degradation of micropollutants over different procedural steps

The degradation of the respective micropollutant over the different procedural steps varies and is respectively specific for the individual substances. The demonstrated deviations from the average values represent the fluctuations of the specific concentrations of substances in the influent of the wastewater treatment plant. The shown fluctuations during ozone stage and downstream filters result from the adjustment of different ozone dosages applied. The substances sulfamethoxazole and ibuprofen are preferentially degraded via the biological stage. Due to the ozone stage and the downstream biologically active filters ibuprofen is further degraded, so that a 2.5 log reduction was achieved. The substances carbamazepine, metoprolol and benzotriazole are not biologically degraded. Carbamazepine reacts very well with ozone and is primarily degraded in this step. Metoprolol and benzotriazole react moderately with ozone and achieve a lower degradation (approx. 50 – 85%). For these substances, the downstream anthracite filter degrades only a low proportion as well. The adsorber filled with granulated activated carbon adsorbs a larger proportion of these substances.

As a result, it can be said that due to the combination of ozone oxidation and filtration an almost complete reduction of different substances can be achieved. Because of this, this process combination provides an effective protection of waters against negative consequences of micropollutants. Depending on the ozone dosage, it is possible to reduce the load of a variety of substances. Ecotoxicological tests (YES/YAS, Microtox) did not reveal any abnormalities, neither after the ozone stage nor after the filter stages. Estrogen effects have been demonstrably reduced by ozonation to an acceptable extent.

THE OXELIA PROCESS

The industrial solution resulting from these experimental series and the new requirements is the Oxelia system which contains an oxidation stage and a biologically active filtration stage. The process is perfected by a sophisticated integrated control concept based on robust, proven WTW spectral photometers that are easy to maintain and enable a precise dosage and process control and ensure that only those quantities of ozone are generated as required - thanks to the integral process control.

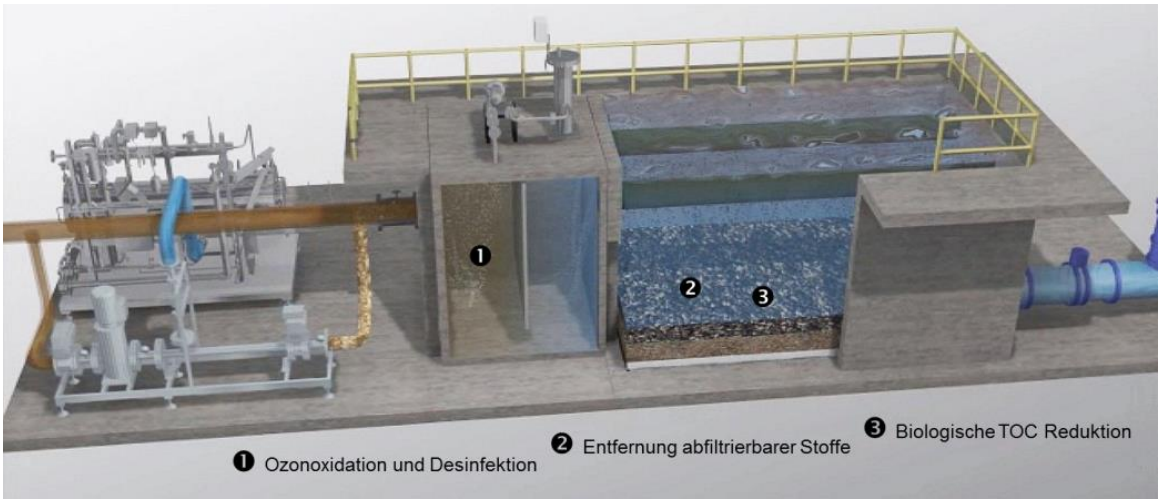

Figure 4: Schematic representation of the Oxelia process

The oxidation stage consists of proven components of Wedeco, having been active as a competent partner in the research of elimination of trace elements for more than fourteen years. This expertise is emphasized by a multiplicity of municipal and industrial plants in Europe as well as by installation of more than 2,000 ozone systems in all over the world. The core component is the ozone generator, equipped with the energy-efficient Effizon evo 2G electrode which apart from high ozone-gas concentrations and higher cooling water temperatures features considerable energy savings. Further components perfecting the overall concept of the oxidation stage are the introduction system, cooling technology, current safety technology and residual ozone destruction.

The filtration stage is based on the advanced filter base concept of Leopold, which can fall back on 80 years of experience in the field of filtration. Thanks to this technology a flat filter base is realizable, saving construction volume effectively and either enabling a larger driving gradient or deeper filter beds of the same construction volume. The patented filter base provides substantial advantages in the backwashing process, since constant backwashing across the entire filter surface effectively avoids dead zones or coning in the filter bed. Thanks to the modular construction retrofitting existing filter units with a Leopold filter base is possible as well. Different filter materials such as anthracite or granulated activated carbon may be applied depending on the task. The integrated process control enables the automatic adaptation of backwashing and pressure surge cycles so that an efficient operation of the biologically active filter is possible. A simultaneous phosphorus and nitrogen elimination is also possible.

The process is perfected by the measurement technology of WTW which thanks to robust sensor technology provides values required for an efficient operation mode. In this process, the latest sensors in the field of UV-VIS and UV sensors such as CarboVis or NiCaVis are applied. These sensors enable the online measurement of sum parameters such as COD or DOC and individual parameters such as nitrite, SAC or solid content and transmission to the process control. The result is an optimized use of ozone as well as a rinsing process of the filter suited to demand.

Table 3: Scope of delivery of the Oxelia system

Oxelia oxidation-enhanced biologically active filtration system		
Ozone WEDECO a xylem brand	Filtration LEOPOLD a xylem brand	Sensor technology WTW a xylem brand
Integrated process control system with connection to superordinate control		
• Oxygen generation (optional) • Ozone generator • Gas distribution and control • Cooling system • Ozone introduction and reaction • Residual ozone destruction • Container installation (optional)	• Filter base • Filter medium (sand, hydro-anthracite or activated carbon) • Filter protective layer • Valve technology • Pumps • Blowers • Filter installation (distribution, backwashing)	• SAC • TOC, DOC, COD • Nitrite / Nitrate • Turbidity, suspended solids

Thanks to the Oxelia system the customer obtains the new treatment process from a single source. The collective experience of the individual brands results in a demand-oriented and efficient system that meets current and new wastewater requirements in a durable and efficient way with easy operation.

LITERATURE

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