



Overview (Source: Hydro-Elektrik GmbH)

## Expansion of the Ozone Bio-Filtration System for Drinking Water Treatment of a Norwegian Island Municipality

The Norwegian “Øygarden municipality” in the province of Hordaland is an island municipality consisting of several islands – located off the coast of Bergen at the edge of the North Sea. The population is approximately 4,700. A very diversified industry is also located in Øygarden. To ensure the supply of drinking water from two existing waterworks, an additional waterworks was built in 2009. The waterworks was designed at that time for a water production quantity of 150 m<sup>3</sup>/h (3,600 m<sup>3</sup>/d). However, an expansion to 250 m<sup>3</sup>/h (6,000 m<sup>3</sup>/d) was already taken into account with regard to the building and the system. The expansion was realised in 2014 after blue-green algae resulted in the failure of another water source and the supply had to be quickly assumed by the new waterworks.

Surface water from the inland lake “Størvatnet” located just a few metres above sea level (Figure 1) is used as raw water for the drinking water supply. The ozone bio-filtration process was chosen to reduce the colour and the total organic carbon (TOC) and to increase the hygienic safety according to the multi-barrier principle. To achieve a high degree of safety for the water supply, all important components were planned so that even in case of a partial failure, a high degree of operating safety exists and the water supply is maintained or a partial failure only results in minimal disruptions.

### Raw water supply

The water treatment plant was built approx. 250 m from the lake at a height of 12 m above the water level. The construction of a pumping station with its base below the water level was planned for the required raw water supply. The water was to flow into the station by means of geotetic pressure via the seawater lines and was to be pumped to the water treatment plant by submersible pumps. However, this design would have required enormous efforts during construction due to the rocky ground and the great water

level fluctuations (up to 1.5 m) involved. On the suggestion of Hydro-Elektrik GmbH, the supply system was therefore planned as a vacuum system. This enabled the pumping station with a simple design to be located in the dry area above the water level. The raw water was extracted via two redundantly designed DN 300 suction lines which are each individually piggable. The lines run together in the pumping station and are kept at a vacuum with a vacuum system. The pumping station is equipped with four speed-controlled submersible pumps

(**Figure 2**), each of which is installed individually in evacuated suction jackets. The vacuum system consists of two liquid-ring vacuum pumps operating in alternation with an output of 1.45 kW each and a lying vacuum reservoir equipped with level switches to control the vacuum pumps which operate with a suction of up to 1,000 mbar. This ensures that the suction jackets of the submersible pumps are always filled with water, regardless of the water level in the lake, and the raw water supply can be continuously provided.

In normal operation the maximum pumping rate is 260 m<sup>3</sup>/h. The raw water supply is routed together in one line on the delivery side after the pumps and is pre-filtered with a fineness of 50 micrometres via a self-rinsing fine filter also installed in the pumping station. The filter with a DN 300 design operates continuously, however requires a certain working pressure for operation for the reliable back-flushing of the filter elements. For this reason, the raw-water pumping station operates like a pressure booster system with constant output pressure. One to four pumps are connected depending on the water requirement of the treatment system. The required output of the pumps is 11 kW each.

**Ozone bio-filtration**

In recent years, ozone bio-filtration has established itself successfully in drinking water treatment applications. Practical examples in Germany, Scandinavia and the USA illustrate that with ozone bio-filtration, it is possible to realise reliable and economical drinking water treatment plants [1, 2]. The NOM (natural organic matter) content is important in the case of water that is intended for use as a drinking water supply. The NOM concentration is analytically calculated as the sum of the dissolved organic carbon (DOC). Typical DOC levels are 3 to 6 mg/l. DOC levels up to 8 mg/l can occur in surface waters. In particular, the DOC levels from vegetable decomposition processes are decisive for the colouration. Water with increased DOC levels should not be used for the drinking



**Figure 1:** Størvatnet inland lake (Source: Hydro-Elektrik GmbH)



**Figure 2:** Raw water supply (Source: Hydro-Elektrik GmbH)

water supply without water treatment. This is because even supposedly stable water can have a tendency towards a sudden and sharp increase in germs after oxidative water treatment (e.g. adding disinfectants). Ozone bio-filtration is a proven method for the treatment of water containing humates. Under the influence of ozone as a strong oxidation agent, the organic carbon compounds with a high molecular weight are split and the concentrations of the compounds with a low molecular weight are increased. Part of the compounds created in this way is biologically available and can be biologically degraded in the downstream (bio-)filtration stage.

**Water treatment system**

The task of the new water treatment system is the reduction of the colour and the DOC/TOC and an increase in the hygienic safety. The new system is based on the process steps:

*Pre-filtration – Ozonation – Reaction – Bio-filtration – UV treatment – Water glass dosing – Chlorination*

Each system consisting of five parallel treatment lines (**Figure 3**) contains a highly effective ozone-mixing system, a standing ozone reaction tank (D = 1,000 mm and H = 6,000 mm) with a return loop and a downstream filter



Figure 3: Water treatment plants (Source: Hydro-Elektrik GmbH)

Mass transfer area of gas bubbles with  $V_{total} = 1 \text{ dm}^3 = 1 \text{ l}$

- Ball volume:  $V = 1/6 * \pi * d^3$
- Surface:  $A = \pi * d^2$

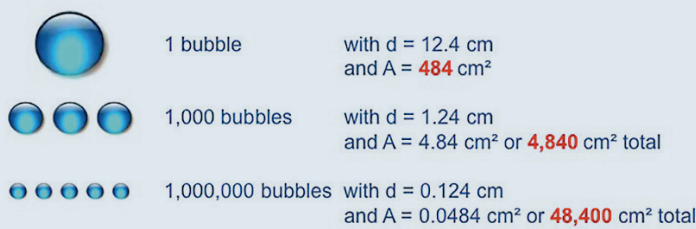


Figure 4: Gas exchange (Source: Hydro-Elektrik GmbH)



Figure 5: Ozone generation (Source: Hydro-Elektrik GmbH)

( $D = 3,200 \text{ mm}$  and  $H = 4,000 \text{ mm}$ ) with stainless-steel filter vessels for bio-filtration. With ozone systems – in particular with high doses and lower temperatures – the mixing system is decisive for the effectiveness of the system. Ideally, all ozone fed in is mixed with the water, dissolved and completely consumed. Very high input levels are possible with venturi injection systems. Mixing with the finest possible bubbles is imperative for an optimum mass transfer, as is clearly illustrated in **Figure 4**. Due to the many small bubbles, the surface is maximised for the mass transfer. Here driving forces for the mass transfer are the concentration and partial pressure differences at the gas/water boundary surface. In addition

to the spontaneous reactions in the area of ozone mixing, the subsequent reaction time also plays a major role. It is characteristic of reaction systems that the ozone content continually decreases in the direction of flow through the reaction tank as a result of ozone reactions and ozone breakdown. High CT values (Concentration \* Time) in comparatively small reaction tanks can be achieved with a return loop in which up to 30% ozonized water is fed back to the mixing system. However, this must be taken into account when dimensioning the venturi system. Additional packing is no longer required with these systems.

The filter vessels are designed as multi-layer filters. Type CC active carbon serves

as a major filter layer. When the active carbon is flowed through, rest ozone is broken down and with it the basis is laid for the subsequent bio-filtration. In normal operation, the residual ozone content in the filter overflow is approximately 0.3 to 0.5 mg/l. This always ensures outstanding disinfection. The flow rate through each filter is detected with a magneto-inductive flow meter and controlled or limited by the automatically operated control valve at the system inlet. All ozone is effectively removed in a catalyst from the minimal exhaust gas quantities containing ozone which result when venting the filter.

The maximum filter speeds for ozone bio-filtration are approximately 6 to 7 m/h.

Filter rinsing is only carried out with water from the pure water tank. The rinsing program is matched to the filter.

### Ozone system

The ozone generation system (Figure 5) features a redundant design with two lines, with each line designed for full-load operation. Each of the ozone generators has an output of up to 1,800 g/h with an ozone concentration of 10% (wt), which enables an ozone dose of up to 7.2 g/m<sup>3</sup> water. The water-cooled ozone generators with a maximum power consumption of 25 kW are cooled with an internal cooling water circuit with demineralised water. The heat is transferred to the cooling water flowing through via the heat exchanger.

Due to the high concentration of the mixture containing ozone and oxygen of 10% (wt), a small amount of oxygen can be used. An oxygen quantity of 12.2 Nm<sup>3</sup>/h is required for the maximum ozone output of 1,800 g/h.

The oxygen is generated locally with two Hydroxymat 150 generator lines. Each line can generate a quantity of up to 15 Nm<sup>3</sup>/h. As a result, complete redundancy is also provided here. Oxygen is generated through concentration of the atmospheric oxygen with a purity of up to 90%. Each generator line consists of a screw compressor unit (nominal capacity = 3.15 m<sup>3</sup>/min) with an integrated compressed-air dryer, a compressed-air tank with a capacity of 900 l, a PSA generator and an oxygen tank with a volume of 470 l. The oxygen is concentrated or enriched in the PSA (Pressure-Swing-Adsorption) generator with molecular sieves. The proportion of nitrogen is dissipated to the outside. PSA generators operate very reliably and efficiently.

To monitor the oxygen and ozone generation systems for leaks, the room air in the production and operating rooms must be monitored with sensors and automatic evaluation.

### UV system

A UV system (Figure 6) is connected downstream of the ozone bio-filtration systems as a second barrier. The UV system



Figure 6: UV system (Source: Hydro-Elektrik GmbH)



Figure 7: Pure water supply (Source: Hydro-Elektrik GmbH)

consists of a total of three lines which are dimensioned so that two systems are sufficient for maximum operation. Each line is provided with a flow meter and a regulating device to ensure that the maximum permissible flow rate is not exceeded and disinfection is always guaranteed. The minimum UV dose is 400 J/m<sup>2</sup>.

### pH correction

Norwegian surface waters are only very slightly mineralised and therefore generally have pH values which are too low. In many cases, small quantities of water glass (sodium silicate) are therefore dosed to increase the pH and for corrosion protection. The water glass is dosed with dosing pumps in

proportional quantities at the end of the process following treating or UV treatment.

### Pure water storage tank

The treated drinking water is temporarily stored in the pure water storage tank with a capacity of 1,500 m<sup>3</sup>, a diameter of 18 m and a height of 6.0 m. Three high-pressure pumps (Figure 7) with an output of 30 kW each pump the temporarily stored drinking water to the distribution system or into the next higher elevated tank. Submersible pumps, which are also installed in the suction jackets, are used here to pump the water. To bridge a brief power failure, an emergency power system is provided which enables operation of the pure water pumps to be able to use the entire volume of the pure water storage tank accordingly.

### Operation and control

All system components necessary for the operation can be safely accessed from the operator platform. The system is controlled

automatically with PLC systems with touch-panel operation and connection to the higher-level control system of the municipality. Fast help is also ensured by the manufacturer by remote control if malfunctions occur.

### Summary

Ozone bio-filtration is a very high-performance process for treating and providing drinking water. The system with three filter systems and an output of 150 m<sup>3</sup>/h, which was put into operation in 2009, was expanded in 2014 with two additional systems to provide the maximum output of 250 m<sup>3</sup>/h of drinking water. Since being commissioned, the system supplies drinking water in accordance with the requirements of the applicable drinking water ordinance.

### References

- [1] *Brugger, M:* Treatment of waters containing humates with ozone bio-filtration, wvgw Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, energie | wasser-praxis 4/2006, p. 40–43

- [2] *Brugger, M:* Ozone Bio-Filtration – a powerful process for treatment water containing humates, wvgw Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, bluefacts 2012, p. 138-143

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