Groundwater plant with treatment system to remove manganese

A completely new treatment system for deacidification and manganese removal has been built to supply water to the Norwegian town of Hønefoss (Ringerike kommune) (**Figure 1**). With a capacity of 230 l/s, the plant has been equipped with the latest technology from the Ravensburg-based HydroGroup®. The German company and its Bergen-based Norwegian subsidiary Hydro-Elektrik AS managed to impress with their proposed solution and beat off the Norwegian competition during the bidding process.

Water has been supplied to Hønefoss and the surrounding area through the Ringerike waterworks since 1987. The current daily water output is about 7,000 m^3. Initially, the water was pumped from three groundwater wells in a gravel deposit in Kilemoen, north-west of Hønefoss. The slightly acidic water used to be intensively aerated for deacidification in the inlet to the elevated tank only. The system supplied drinking water for current needs until around 2006 when problems suddenly arose with manganese deposits. The manganese content in the drinking water had increased unnoticed with deposits spreading throughout the entire supply network [1].

Problem

A local sausage manufacturer detected black particles on its sausages and staining in its production water. A total of three incidents brought sausage production to a standstill, which entailed enormous additional costs. Equipment became clogged at dental practices, but the most serious incident was the closure of emergency care and a surgical department at Ringerike Hospital due to defective equipment in 2015. Many complaints were received about stained laundry and brown water. Some water meters also became blocked.

The first measure to overcome the problem in the three wells was to replace the existing groundwater pumps with speed-controlled pumps and build three new, shallower wells. After a series of evaluations and tests on various types of processes in Norway and abroad, a solution was found based on ozonation and filtration. After several years of thorough planning, the new waterworks was commissioned in 2018 and its capacity was been designed ready to meet future water requirements. Strong population growth is expected in the region as the new Ringeriksbane railway line and the new E16 road are progressively being built in the area, significantly improving access to the expensive Oslo economic area [2].

Manganese

Water with a high manganese content (> 0.05 mg/l) requires treatment. Water containing manganese is generally reduced-oxygen or low-oxygen water in which the manganese is present, dissolved in bivalent form as Mn^{2+}. Like iron, manganese is a heavy metal that is normally only present as an oxide in the earth's crust. During the course of leaching, water, the oxygen content of which decreases over time due to biological processes, comes into contact with these oxides in deeper layers of the earth. If the oxygen content is low, redox processes in the soil reduce oxides and the manganese released during processes is dissolved in water. When drinking water is transported, the water comes into contact with

Figure 1: *Kilemoen waterworks*

oxygen again, meaning manganese is oxidized once more. Oxidized manganese is precipitated from water and forms black deposits in pipelines and drinking water storage systems, which can cause huge problems and lead to complaints from consumers.

Like deferrization, demanganization is one of the oldest water treatment processes along with filtration. Oxidation of manganese is slower than that of iron. If high levels of iron and manganese are present together in water, two-stage filtration is often provided after a necessary increase in oxygen. Deferrization takes place in the first stage and demanganization in the second. During demanganization, the soluble divalent manganese is oxidized with oxygen to form insoluble manganese oxide (manganese dioxide). If ozone is used, manganese can be dependably removed in one filter stage together with iron and any arsenic that may be present. The advantage of ozone oxidation is complete demanganization with no run-in-time required. Ozone also disinfects the water at the same time.

Ozonization with subsequent filtration was chosen for the Kilemoen system as it is already a familiar process that has been successfully used for years in the Norwegian localities of Bø, Hjartdal, Gausdal and Granvin. Plant and process technology by the Ravensburg-based HydroGroup® is also used in these localities.

Oxygen generation

Modern ozone production systems use oxygen as a feed gas. The advantage of oxygen is that significantly higher ozone concentrations can be achieved with the same energy input. Moreover, no nitrogen oxide is formed, which would otherwise produce corrosive nitric acid when it reacted with water. As a general rule, liquid oxygen (LOX) is used as a feed gas in large systems. In medium-sized and smaller systems, it is more economical to produce oxygen on site. What are known as PSA systems produce oxygen in this case. PSA stands for pressure swing adsorption. During this process, compressed air is alternately applied to what are known as molecular sieves and oxygen from air is concentrated to up to 95% [3]. The compressed air is produced by screw compressors with a motor output of 7.5 kW each. The heat energy produced as a waste product is fed into the heating network via heat exchangers (**Figure 2**). The compressed air is dehumidified and extremely finely filtered via several filter stages (oil separator, activated carbon filter, coalescence filter). It is then fed into the PSA systems at the purity and quality standard required for foodstuffs. The entire oxygen generation process takes place fully automatically in three completely independent lines with a high level of redundancy. The system can produce 3 x 6.2 Nm^3 of oxygen per hour (**Figure 3**).

Ozone generation

Ozone is produced via modular air-cooled plasma generators with a capacity of 125 g ozone per hour, which are built into two stainless steel cabinets with six modules each (**Figure 4**). Each filter line has its own separately adjustable generator.

Figure 2: *Compressed air generation with screw compressors and heat exchangers*

Figure 3: *PSA systems for oxygen generation*

Figure 4: *Ozone production systems in cabinet design*

Figure 5: *Filter vessel with ozone mixing and reaction system*

Figure 6: *Top operating level of the ten filter systems*

As there are ten filter systems, one module is kept in reserve in each cabinet. This configuration means that there is also a high level of redundancy in the ozone generation system. Ozone breaks down into oxygen during oxidation. Thanks to the modular design with independent lines, the ozone can be produced in the required quantity and dosed precisely. If ozone is used to demanganize, it should be noted that if the dosage is too high, manganese oxide can possibly be oxidized to permanganate, resulting in pink water. For this reason, the ozone concentration downstream from the ozone generator should not be too high.

A speed-controlled pump is installed at the inlet to each filter to regulate the water flow through the filter and compensate for the increasing pressure drop across the filter bed during filtering (**Figure 5**). The ozone is mixed into the raw water in the contact tank upstream from the reaction tank using a combined venturi/injector system in the full flow.

Figure 7: *Lime silo with controls and water jet pump*

Filtration

The actual filtration of the oxidized manganese takes place in ten stainless steel pressure filters 3,200 mm in diameter and 4,000 mm high (**Figure 6**). The maximum filter speed is about 11 m/h. The filter height is due to the fact that the filters also contain calcium carbonate in addition to quartz sand and filter carbon. The upper part of the filter separates the manganese while, in the lower part of the filter, the carbon dioxide contained in the raw water reacts with the calcium carbonate, which dissolves slowly, producing the desired increase in alkalinity. The calcium carbonate needs to be replenished with new material on a regular basis. Calcium carbonate is stored in a closed silo for this purpose. A volume of 30 m^3 was chosen for the silo to ensure that a silo truck can blow in a full load if required. Filter refilling is automatically controlled via a sluice with a water jet pump and a closed stainless steel pipe system (**Figure 7**).

UV disinfection

A final UV treatment system has been installed to ensure hygiene. Each UV system line is fitted with automatic valves, a flow meter and an automatic wiper system (**Figure 8**). After the UV system, the pure water is fed into the existing tank with a capacity of 2,000 m^3 and into a new stainless steel tank with a capacity of 3,000 m^3. Both tanks communicate via the extraction line.

EMSR

Complete automation and programming of the fully automated system also form part of the service. The system is integrated into a higher-level SCADA system via interfaces. Several touch panels are used to operate the system and provide visualization on site. All automatic fittings are connected via an ASi bus. The solenoid valves for the compressed air are integrated directly into the fitting. Each fitting can also be operated manually in addition to normal automatic mode.

Ventilation and safety

Since the system needed to be built next to a quarry, there were special requirements for air renewal and cooling air supply. To ensure that as little air as possible needs to be fed into the building, an internal air ducting system was designed with a circuit in compliance with fire protection requirements. The waste heat from the machine rooms is fed into the filter hall, where the air cools and is then fed back into the machine rooms via the pipe basement connected to the filter hall. Hardly any air dehumidification is required thanks to this circulation system. Sensors for measuring the oxygen and ozone content are installed at various points to monitor the room air quality. In the event of any oxygen or ozone leakage, the system would immediately be taken out of operation, the room air extraction system activated, and an alarm triggered.

Summary

The system supplies excellent pure water with a very low turbidity (< 0.1), a manganese content of less than 0.001 mg/l and a pH value of more than 8 with a calcium content of around 24 mg/l. The clean water guarantee provided by the process supplier has delivered what was promised and the operators are satisfied. The total cost of the system, including the tank, was around 100 million kroner, which is some 20 million kroner less than the estimated budget (10 kroner is about 1 euro). Backwash water and first filtrate account for about 1% of the pure water production, which is an excellent figure.

Figure 8: *UV system for final disinfection*

References

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