OZONE BIO FILTRATION

– a powerful process for treatment water containing humates

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Source: Antikainen – veer.com

Ozone bio filtration is an established method for treatment water containing humates and other undesirable substances. Under the influence of ozone as a strong oxidation agent, the organic carbon compounds are split and the concentrations of assimilable organic materials increase. In addition to the fundamental basics, the results from different operational plants will also be outlined in this article.

Die Ozon-Biofiltration ist ein anerkanntes Aufbereitungsverfahren für Wässer mit Huminstoffen und anderen unerwünschten Wasserinhaltsstoffen. Durch den Einfluss von Ozon als starkes Oxidationsmittel werden organische Komponenten aufgespalten und die Konzentrationen von assimilierbaren organischen Materialien erhöht. Im Artikel werden neben den Grundlagen Erfahrungen und Ergebnisse in Betrieb befindlicher Anlagen aufgezeigt.

Fig. 1: Wisconsin River: Brownish water due to NOM

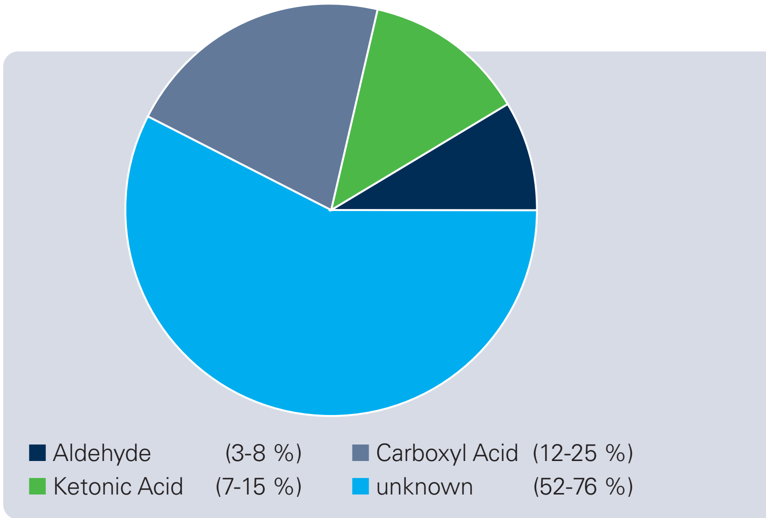


Fig. 2: Percentages and types of assimilable substances

The NOM (natural organic matter) content is important in the case of water that is intended for use as a drinking water supply. Normally, the NOM concentration is analytically calculated as the sum of the dissolved organic carbon (DOC). Typical DOC levels are 3 to 6 mg/l. Much higher values are possible in surface waters. In northern Germany too, DOC levels of up to 8 mg/l have been found in the groundwater under sandy soils.

The colour numbers are between 20 and 60 mgPt l^{-1} (platinum-cobalt units on the Hazen scale), and in individual cases up to in excess of 100 mg Pt l^{-1}, whereby the colour does not necessarily correlate to the DOC. The pH values of these mostly slightly mineralised waters are in the slightly acidic range of between 5.5 and 6.5.

NOM colours the water a yellowish brown and results in a sometimes unpleasant musty odour and taste **(Fig. 1)**. When ordinary chemical disinfectants are used (e. g. agents containing chlorine), NOM reacts significantly to the disinfectants. This reduces the actual disinfection strength, and this must be compensated for by using more disinfectant. This inevitably also increases the production of unwanted disinfection by-products (DBP). When there is UV radiation, NOM also causes destabilisation due to scatter and absorption. For this reason, removing or reducing NOM plays a central role during the drinking water treatment process.

High DOC levels

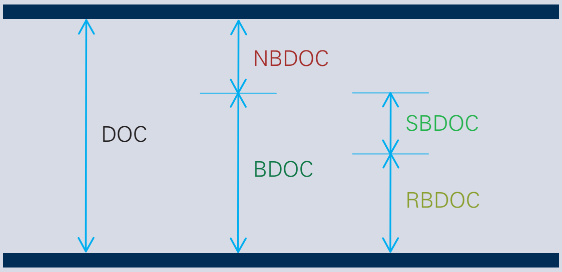
The DOC level is a sum parameter that covers the totality of all dissolved organic plant and animal materials. Some DOC molecules have a defined chemical structure and are easy to detect analytically. However, most of the molecules are not easy to detect and are grouped together under the heading humic acids or humates. The graph shows a possible distribution of the various groups of materials **(Fig 2)**.

In particular, the DOC levels from vegetable decomposition processes are decisive for the colouration. Like when making tea, the colour increases along with the exposure time and concentration. Water with a high DOC level should not be used to supply drinking water unless it has been treated. Humates represent the end products in the natural biological material cycle. They cannot biodegrade much more. Even supposedly stable water can have a tendency towards a sudden and sharp increase in germs after oxidative water treatment (e. g. adding disinfectants). However, besides a possible increase in germ levels in the pipeline network caused by assimilable organic carbon (AOC), attention must also be paid to the formation of unwanted reaction by-products such as trihalomethanene (THM) in conjunction with the use of disinfectants containing chlorine.

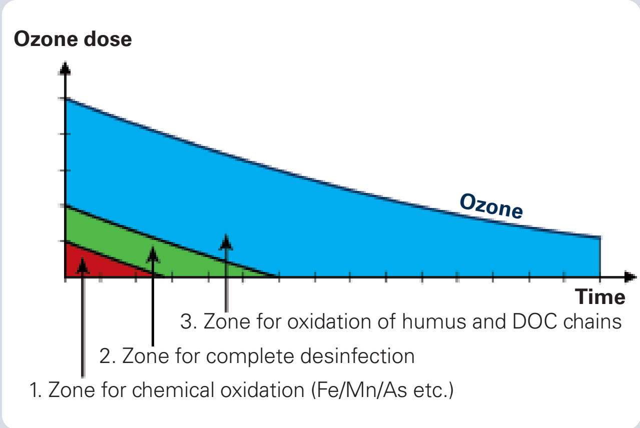
Processes for treating waters containing humates

Various processes can be used to treat waters containing humates. Here, the choice of process must be based on the respective prevailing water quality and, to some extent, also on the volume of water to be treated. Due to the size of the humate complexes, they can be separated out from the water very well by nanofiltration (NF). Nanofiltration systems require operating pressures of between 4 and 8 bar and raw waters of low turbidity. When turbidity is greater, upstream sand filtration or ultrafiltration is required. Chemical cleaning agents are required in order to prevent fouling on the membrane surfaces. These agents in particular cause wastewater pollution, which when introduced directly into surface water must be regarded as critical and necessitates costly wastewater treatment measures. Membrane systems are the preferred choice in smaller systems and at high colour levels/high DOC.

The ion exchange process for removing humates which is possible in principle has not become established in drinking water treatment. Coagulation processes are more widespread. In these processes, the humates are precipitated by means of a high dosage of flocculants (aluminium sulphate, polyaluminium chloride or iron (III) chloride) upstream of or in a filtration stage. Coagulation systems produce



DOC	Dissolved Organic Carbon
NBDOC	Non Biodegradable Dissolved Organic Carbon
BDOC	Biodegradable Dissolved Organic Carbon
SBDOC	Slow Biodegradable Dissolved Organic Carbon
RBDOC	Rapid Biodegradable Dissolved Organic Carbon



Sources: Hydro-Elektrik GmbH

Fig. 3: Graph and key to the abbreviations

Fig. 4: Reaction kinetics, ozone – water

high sludge loads. The advantages of these systems are felt particularly in large systems and where there are high DOC levels.

Safe and environmentally friendly ozone biofiltration is a preferred process for treating waters containing humates, particularly when decolouration and disinfection are defined as aims of the water treatment. 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. This process also increases the levels of biodegradable dissolved organic carbon (BDOC) and almost completely destroys the substances providing colouration – provided that there is a sufficient dose of ozone **(Fig. 3)**.

The described conversion of the DOC into assimilable substances also explains why an ozonation stage must always be followed by a biologically optimised reactor. This is normally a filter stage with downward flow, constructed specifically as a bioreactor and in which reduction of the amount of nutrients takes place in a completely natural way. The zone with the highest level of biological activity is in the upper filter bed, because this is where the largest amount of nutrients with rapidly biodegradable substances is present. One of the advantages of ozone biofiltration is that the process produces no sludge or large amounts of concentrated salt loads, with ozone eliminating the pollution to a certain extent instead.

Ozonation

Realistic ozone doses are between 0.8 and 1.5 mg O_3/mg DOC. Standard values of up to 0.15 mg O_3/mg Pt can be expected where there are very high colour levels. It is obvious that at such high doses, excellent and fine-bubbled mixing-in of the ozone followed by blending is extremely important. The reaction with slow-reacting water constituents takes place in the downstream reaction tank. The sub-

Source: jarma – Fotolia.com


Fig. 5: Water treatment plant, Brattvåg

Source: Hydro-Elektrik GmbH


Fig. 6: Ozone mixing

Source: Hydro-Elektrik GmbH

stances providing colouration have already been destroyed shortly after the initial reaction. The chemical reactions with metallic water constituents such as iron, manganese and arsenic also take place spontaneously. The disinfection, in which viruses, parasites and germs alike are reliably killed due to the high concentration time (CT) values, occurs parallel to the oxidation **(Fig. 4)**.

Filter design

The filter in an ozone bio filtration system must fulfil several tasks. Besides breaking down residual ozone in water – a prerequisite for biological activity – and holding back turbidities, particles and viruses, the filter must also be a good bio-reactor. In principle, biological colonisation occurs on almost all filter materials. However, it must be noted that filter systems used in water treatment must also cover downtimes.

In the first few weeks, activated carbon takes on a very heavy load of organic materials, and therefore also probably represents a source of nutrition for the micro-organisms during filtration downtimes. The colonisation of a filter with activated carbon also occurs more quickly than is the case with other materials. The water temperature has only a slight influence on the bioactivity and breakdown rates with respect to the DOC, which can be over 30 percent. Biologically active filters should only be flushed with water. Depending on the filter design, flushing water quantities vary between 22 and 45 m/h.

Practical example

Hydro-Elektrik GmbH set up ozone bio filtration plants for several Norwegian communities. The system described below, with a measured treatment output of around 360 m^3/h, was set up in Brattvåg near Alesund in 2010/2011 **(Fig. 5)**. A new waterworks had become necessary due to increasing colour in the raw water, the wish for two independent hygienic barriers and a required increase in the treatment capacity. When it came to choosing the process, coagulation, nanofiltration and ozone biofiltration were compared with each other as current process solutions. The ozone biofiltration process was selected on the basis of the raw water quality and the cost analyses made. The principle suitability of the process was confirmed by SINTEF on the basis of water analyses and pilot trials.

The natural lake "Store Hestevatnet", from which the water is taken at a depth of approximately 17 m, serves as the raw water source. The 0.53 km^2 lake, the maximum depth of which is 60 m, is 260 m above sea level. First, the collecting pipeline carries the water into a pressure reduction reservoir 100 m lower down, and then to the water treatment system 95 m above sea level. This allows the water to be transported through the water treatment system under its own pressure. On the infeed side, an automatic backwash protection filter (Boll filter) is installed first, protecting the two parallel pressure reducing valves downstream. The valves regulate a constant input pressure of 2 bar.

Source: Hydro-Elektrik GmbH

Fig. 7: UV systems

The actual biofiltration system consists of 6 parallel lines with the following components: ozone mixing, reaction and contact tank, filter vessel **(Fig. 6)**. The ozone is produced in two redundant lines. Only one line is necessary for operation, with the second line being kept in reserve. Each line consists of a screw compressor with an integrated refrigeration dryer, compressed air tank, oxygen generator, oxygen tank and ozonizer. The electronically controlled ozonizers that operate in the inaudible frequency range (23 kHz) enable up to 3,600 g/h of ozone to be produced per unit. The maximum ozone dose is around 10 g/m³, which is also regarded as sufficient for future requirements. The ozone is mixed by means of Venturi valves/injector valves upstream of the reaction and contact tank. After passing through the contact tank, the ozonized water flows into the filter vessel. The filter vessels measuring 3.2 m in diameter and 6.5 m in height have active carbon. The maximum filtration speed is 7.5 m/h. Three UV systems for final disinfection are installed between the filter and the waterworks outlet **(Fig. 7)**.

Costs

The investment costs for the complete process engineering system amounted to approximately €1.85 million. The ongoing operating costs of the ozone bio filtration systems are around 1.0 to 1.5 Cent/m³, which in comparison with other systems puts them in an unrivalled low price range.

Conclusion and outlook

In recent years, ozone bio filtration has established itself successfully in drinking water treatment applications. Experience gained from the ozone bio filtration systems that have been in operation for several years shows that by using tailored process technology, it is possible to produce good drinking water from raw water with high colour levels and increased DOC values. The hygienic safety required for the drinking water supply is always reliably provided. As part of ongoing developments, further process combinations and modifications to the familiar technology are being investigated with a view towards further optimisations. The author is available for questions or discussions on this matter.

Sources:

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