Drinking water

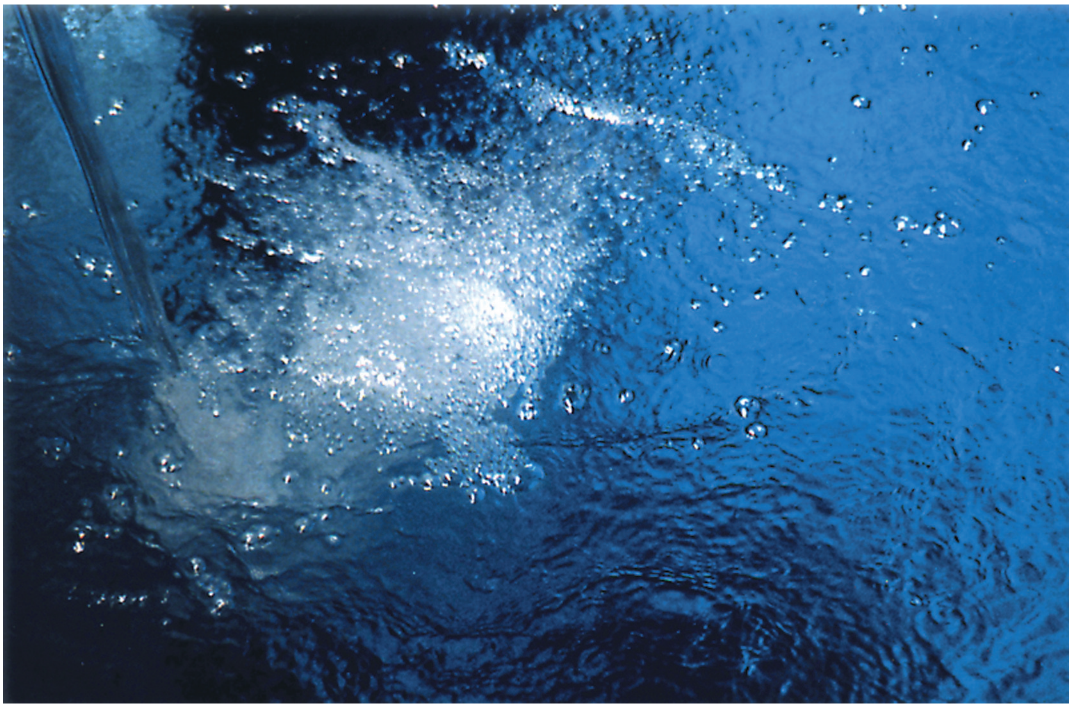
Drinking water is the most important of all foodstuffs. It is irreplaceable. In ancient times „well poisoners“ were mercilessly pursued and faced harsh penalties - often death.

Today water, and drinking water in particular, is protected by laws and ordinances. Public welfare demands comprehensive protection of the water supply to prevent contamination and other problems.

Current problems

Difficulties with groundwater can arise particularly in densely populated areas, in which the catchment areas of water treatment systems are used with increasing intensity. Here, the natural protective and purification effects of the layers above the groundwater are no longer sufficient in all cases to maintain the quality of the groundwater in the long term.

So that sufficient drinking water of perfect quality is always available, it is therefore often necessary to fall back on impure water and to employ problem-orientated water treatment.



Assessing water quality

Depending on its natural origins, water can contain many different impurities. The Drinking Water Ordinance therefore defines the physical and chemical requirements for the water that is used to supply drinking water. However, simply measuring and assessing a few important sum parameters allows conclusions to be drawn about water quality and the usability of a particular water as drinking water.

Redox potential

In every reduction oxidation process of the type that also occurs in water, a state of equilibrium is established after a time. This state can be measured electrically: the redox potential is measured as an electrical voltage between the water and a reference electrode. If the redox potential is negative, reduced substances predominate. If the redox potential is positive, the oxidized substances in the water predominate.

In aerated groundwater, the redox potential is, for example, between 200 mV and 300 mV, and in treated water it is between 700 mV and 900 mV.

Interpretation of the redox potential

A high redox potential means that the pure water now contains hardly any reduced and/or assimilable substances.

For example, with a redox potential of 740 mV and a chlorine concentration of 0.1 mg/l, water can be regarded as sufficiently disinfected - but not if it has a redox potential of 600 mV and a chlorine concentration of 0.6 mg/l. Provided that the system configuration is suitable, the redox potential can be used for the process control of a water treatment system.

Oxygen concentration

Low-oxygen ground water is known as reduced water. Before it can be used as drinking water, it must be treated by oxygen enrichment.

Adding oxygen to a reduced water results in divalent iron (Fe II) oxidizing into the trivalent form (Fe III), enabling it to be filtered out.The addition of oxygen also allows manganese-binding bacteria to accumulate in a downstream filter bed in which dissolved (divalent) manganese is oxidized to form low-solubility brownstone. Oxygen also allows the accumulation in the filter bed bacteria of the species nitrosomonas and nitrobacter, which oxidize ammonium to form nitrate.

Oxygen always has a positive effect on corrosion protection in pipelines. In order to form a sufficient lime rust protective coating in pipeline systems, the oxygen concentration should not fall below 5-6 mg O_2/l.

Capability of oxidation ($KMnO_4$ consumption)

Measuring of oxidizability

The capability of oxidation ($KMnO_4$ consumption) shows the behaviour of the water with respect to oxidisable substances such as oxygen, chlorine, chlorine dioxide, ozone, permanganate and chromate.

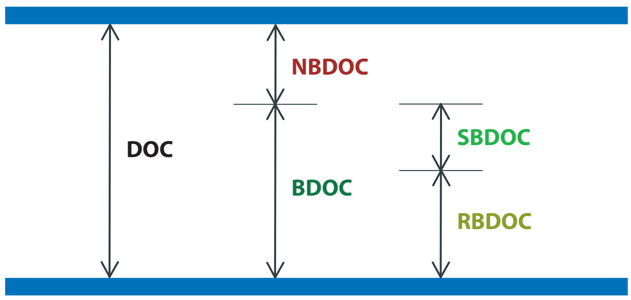
The capability of oxidation of the water is measured by the consumption of added potassium permanganate ($KMnO_4$). A consumption rate of 4 mg/l $KMnO_4$ corresponds to a consumption rate of 1 mg/l O_2.The limit value for the oxygen consuming capacity is (i.e. German Drinking Water Rules) 5 mg/l O_2.

Disadvantages of the process

This process for determining capability of oxidation reacts relatively unspecifically. Some substances oxidize completely, while others display inert behaviour or are only incompletely mineralised. In order to determine the water's organic substances concentration, it is therefore necessary to use other parameters.This is particularly the case if raw water with an anthropogene load is involved.

Alternatives

In addition to the analytical determination of the **D**issolved **O**rganic **C**arbon (**DOC**) and of the **T**otal **O**rganic **C**arbon (**TOC**), a UV absorption measurement can also be carried out at a wavelength of 254 nm.



DOC	**D**issolved **O**rganic **C**arbon (Gelöster organischer Kohlenstoff)
NBDOC	**N**on **B**iodegradable **D**issolved **O**rganic **C**arbon (Nicht bioverfügbarer organischer Kohlenstoff)
BDOC	**B**iodegradable **D**issolved **O**rganic **C**arbon (Bioverfügbarer organischer Kohlenstoff)
SBDOC	**S**low **B**iodegradable **D**issolved **O**rganic **C**arbon (Langsam bioverfügbarer organischer Kohlenstoff)
RBDOC	**R**apid **B**iodegradable **D**issolved **O**rganic **C**arbon (Schnell bioverfügbarer organischer Kohlenstoff)

SAK value at 254 nm

Numerous organic substances have absorption bands in the UV range. This property can be used to draw initial conclusions about oxidisable organic water impurities, particularly when the composition of the impurities is relatively constant.

The SAK value is rounded to 0.1 and is given in m^{-1}. Drinking water regulations contain no statement on the SAK value at 254 nm. However, the SAK value correlates with the $KMnO_4$ consumption and the DOC. Continuous SAK measurement allows statements to be made about the trends displayed by the DOC value pattern.

Coloration (436 nm)

Drinking water should be colourless. Coloration and turbidity are quality shortcomings. A high concentration of organic substances in the groundwater, particularly humates, colours the water yellow to yellowish brown. Sewage entering the groundwater or source water, or other physical and chemical impurities, also colours the water.
A colour measurement can be advantageous wherever surface water with a high humate concentration is used.

The colour of the water is measured in an absorption measurement in the visible range with a wavelength of 436 nm, and is output in m^{-1} (colour) or as a Hazen colour in mg Pt/l. The limit value is 0.5 m^{-1} or 20 mg Pt/l.

When used as a quality parameter in a water treatment system, coloration shows how effective the oxidation stage breaks down and oxidizes the substances colouring the water.

Turbidity (FNU)

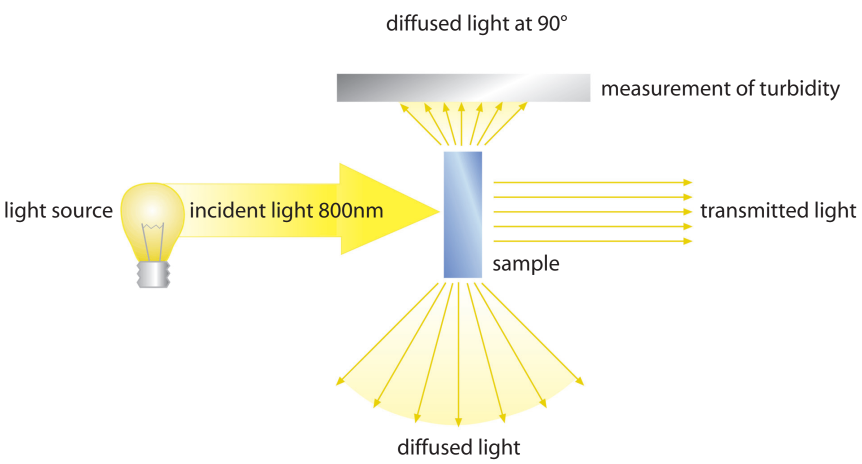
Turbidity in the water arises as a result of mineral or organic solid particles. Water with a high degree of turbidity is always grounds for concern from a microbiological point of view. Drinking water regulation demands that drinking water should not contain any undissolved substances. The limit value is 1.0 FNU (formazine nephelometric units) at the waterworks discharge.

Turbidity in the groundwater and source water in most cases occurs:
- if there is insufficient soil filtration,
- when snow melts,
- after prolonged heavy rainfall.

If soils contain iron or manganese, undissolved substances can also be contained in water from springs.

Schematic depiction

Turbidity measurement process in accordance with EN 270277



In the case of UV disinfection, the turbidity may not exceed values of 0.2 - 0.3 FNU.
By means of a turbidity measurement, it is possible to regulate the dosing of flocculants and / or monitor the performance of filter stages.
It must be noted that very small gas bubbles can influence strongly the turbidity measurement in saturated waters.

Demands places on a modern water treatment system

The drinking water regulations demand that to obtain drinking water, it is only permissible to use bodies of water from which perfect water can be obtained on a long term basis.
This means that modern water treatment must provide drinking water that is equivalent to natural drinking water in terms of quality.

The main tasks of water treatment plants include:

- Hygiene processing (disinfection) of water contaminated by bacteria
- Removing all substances such as turbidities, iron oxide, manganese oxide etc. that represent a physical problem
- Oxidation of reducing substances such as NH^{4+}, As^{3+}, Fe^{2+}, Mn^{2+} ...
- Removing/reduction the assimilable, organic carbon
- Removing/reduction humates and similar compounds
- Removing all highly molecular organic human impurities (CHC, Pesticides ...)
- pH-adjustment (deacidification/neutralisation/softening)

Humates, compounds similar to humates and other highly molecular organic components can be reduced by water treatment. However, since these two groups of materials are in most cases biologically persistent, they are first split by oxidation into biologically degradable fragments and are then mineralised in a biologically active treatment stage.

Following the biological mineralisation of the organic carbon compounds, the water is low in nutrients, which effectively reduces the risk of it being contaminated by germs on its way to the consumer.

Safety of the drinking water

The bacteriological safety of drinking water is defined by, among other things, the limit values for colony-forming units at 20 °C and 36 °C on its way to the consumer.
The hygiene processing mainly also requires the removal of the nutrient potential during the water treatment. In water that is low in nutrients, this means that there is no need for chlorination even in more widely branched networks (example: the water supply for the city of Munich).

Disinfection of the water completes the treatment process. The water can be disinfected by a UV system installed at the filter outlet or by an additional oxidation stage using ozone. Country-specific there can be stipulated a chlorination.

Final oxidation

During final oxidation with ozone, the following processes run simultaneously:

- Disinfection of the water
- Compensation of any oxygen deficit that may have arisen in the filter bed (during non operation)
- Oxidation of nitrite

Chlorination

The so-called safety chlorination or transport chlorination contravenes both regulations and the Minimum Law, and is not permitted for the treatment of drinking water. This means that the addition of chlorine is restricted to emergency cases.
Drinking Water Standards limit the concentration of low-molecular chlorine compounds (trihalogen methane) (THM) - typical reaction products of chlorination - to 50 µg/l.

Irradiation with UV light

The disinfection of water with UV light is a physical process. Under favourable conditions, the UV light damages the microorganisms in the water in such a way that they can no longer produce infection. However, the UV light does not change the water quality. Sufficient treatment is therefore necessary prior to disinfection of the water with UV light.

What is drinking water treatment?

In a drinking water treatment system, raw water is treated in a process with active physical, biological and chemical mechanisms in such a way that at the end of the treatment process, drinking water is available that conforms to the requirements of Drinking Water Standards.

The stipulations standards also include that the available raw water must remain as natural as possible and that only the harmful substances may be removed or reduced to the smallest possible amounts during treatment.

The treatment of drinking water must not be equated with the treatment of process water, in which water is altered to meet industrial needs.
Process water treatment is described in chapter "Industry".

Process steps

Natural drinking water treatment will be orientated towards the processes that also take place in nature for the purification of water. Three main process steps can be recognized here:

- Oxidation
- Filtration
- Hygiene processing/disinfection accompanying the process

The HYDROZON®-Process

What is known as the HYDROZON® process is a natural treatment method that employs the latest knowledge in order to make drinking water from raw water contaminated by geological or human sources.

Stages of the HYDROZON®-process

- Flocculation
- Oxidation
- Filtration
- Biological mineralisation
- Hygiene processing/disinfection
- Monitoring

Sequences and stages in HYDROZON® process

Flocculation

The aim of flocculation is to optimise the filtration process. Flocculants are inorganic electrolytes compensate electrical charges on the surfaces of solids.This results in the formation of micro-flocs and macro-flocs, which in turn form larger agglomerates.
In this way, they allow the filtered separation of colloid-disperse water impurities.

Adding the flocculant

The flocculant is added to the raw water upstream of the filter stage in a reactor. This guarantees optimum mixing and distribution of the flocculant. Ozone also supports micro-flocculation.

1st ozone treatment stage

The following are the main processes that occur during the 1st ozone treatment stage:

- Disinfection of the raw water
- Oxidation of iron to form iron hydroxide that can be filtered
- Oxidation of manganese to form brownstone that can be filtered
- Splitting of highly molecular organic compounds to optimise the biological mineralisation in the filter bed (ozone bio-filtration)
- Oxygen enrichment to supply the aerobic micro-biology in the biologically active filter bed

Oxidation with ozone

In oxidation, elements or compounds are combined with oxygen. In the process the substance to be oxidized emits electrons that are in turn taken up by the oxidation agent.

Ozone is activated oxygen with a high specific oxidation potential (2.07 V).

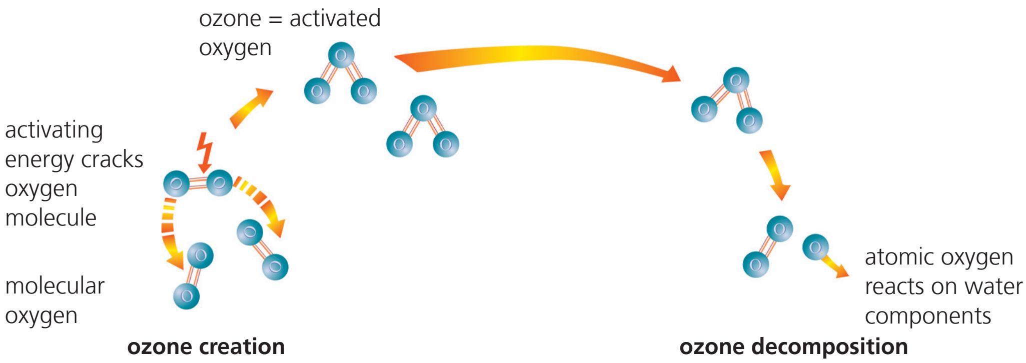
Potentials of important oxidants

Oxidant	Potential in V
Hydroxlic radical $OH^{\bullet}$	2.80
Ozone O_3	**2.07**
Hydrogen peroxide H_2O_2	1.78
Potassium permanganate $KMnO_4$	1.70
Hypochlorite HOCl	1.49
Chlorine Cl_2	1.36
Chlorine dioxide ClO_2	1.27
Oxygen O_2	1.23

Effect of the ozone

Due to its high oxidation potential, ozone produces a very fast oxidation of organic and inorganic water impurities.The HYDROZON® process utilizes ozone to oxidize the raw water and particulary for the final disinfection of the pure water.

Oxidation gives rise to, among other things, low-molecular, assimilable organic carbons (AOC).These substances are mineralised in a biologically active filter bed that follows the oxidation.



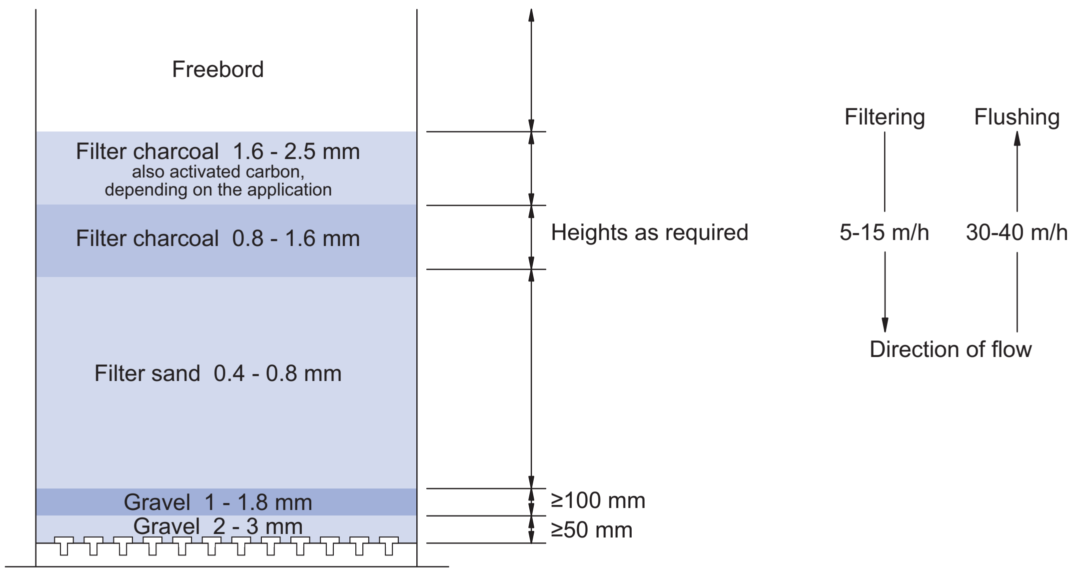
Filtration

In filtration, a liquid containing solid particles is separated into its liquid and solid components.The optimised filter bed retains corpuscular solids and allows through the filtrate, i.e. the filtered liquid.
The following also occur in the filter bed:

- Reduction of residual ozone in the upper filter bed and
- Biological mineralisation of AOC in the lower filter bed

The diagram shows for example the design of a multi-layer filter for the HYDROZON® process:

Typical filter design for the HYDROZON®-process



Criteria for filter performance

The filter performance is particularly influenced by the following factors:

- Filter materials
- Bulk density, grain diameter and grain surface of the filter materials
- Mixability of the filter materials
- Filter height
- Filtering velocity
- Existing raw water quality

Biological mineralisation

Mineralisation process

Highly molecular compounds are split up into low-molecular groups by the oxidation with ozone.The now assimilable organic substances are largely mineralised by aerobic bacteria in the ozone-free layer of the filter bed for the most part to form water, carbon dioxide, nitrogen etc.

This process - splitting through oxidation followed by biological mineralistion replicates and accelerates the natural water purification process taking place in aquifers.

Normally, special appropriately dimensioned activated carbon or multi layer filters are used for the biological mineralisation (ozone bio-filtration process).

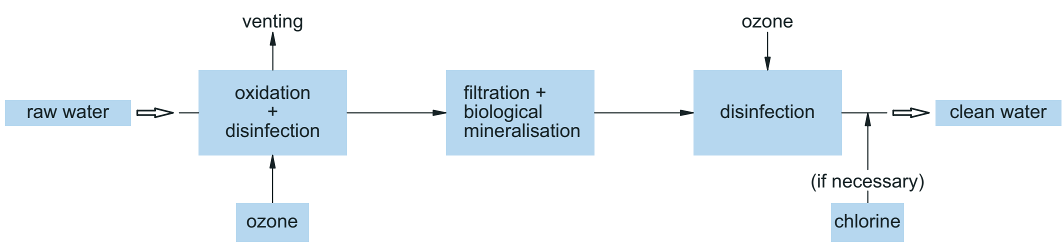
Hygiene processing/disinfection

During disinfection, pathogens are so greatly damaged that they can no longer infect other living organisms. In the HYDROZON® process, the raw water is automatically disinfected since the ozone acts both as an oxidizing agent and as an approved disinfectant.

2nd ozoning

Finally, a second ozoning operation takes place in the HYDROZON® process.
The following processes occur in this ozoning:

- Oxidation into nitrate of nitrite that may have arisen during the biological mineralisation
- Compensation any oxygen deficit that may have arisen as a result of the biological activity in the filter bed
- Disinfection and hygiene processing of the pure water



The final disinfection can also be done with, for example, UV treatment.

Measuring the redox potential

Importance of the redox potential

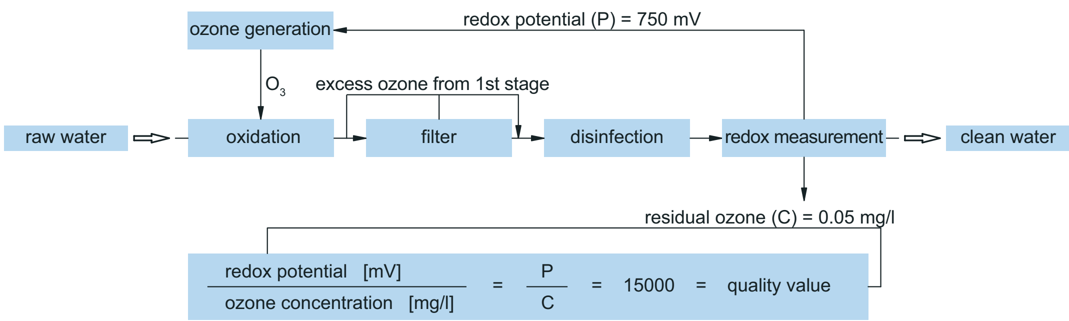
The redox potential provides information about the ratio of oxidized substances to reducing substances. Provided that the system configuration is suitable, the redox potential can therefore also be used as a quality parameter for the process control of a water treatment system.

In the HYDROZON® process, the redox voltage is measured after the final oxidation in the pure water.

The higher the redox potential and the lower the residual ozone concentration, the better the treatment performance

Quality value

If, for example, a redox potential of 750 mV is measured, with a residual ozone concentration of only 0.02 mg/l, this points to a high level of hygiene processing for the water.

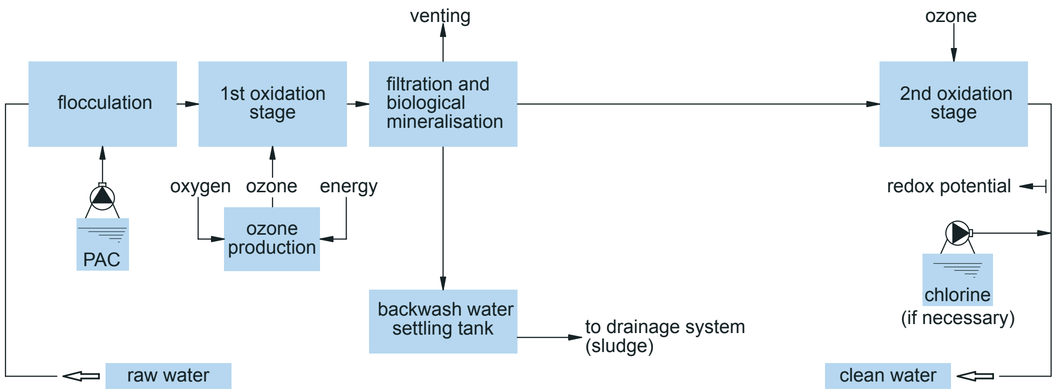


The HYDROZON® process – application examples

In the HYDROZON® process, the treatment problem is solved by means of a proven, tried-and-tested process and by proven, staged performance units.

The basic process

The illustration below shows the „basic method" for treating drinking water in accordance with the HYDROZON® process..

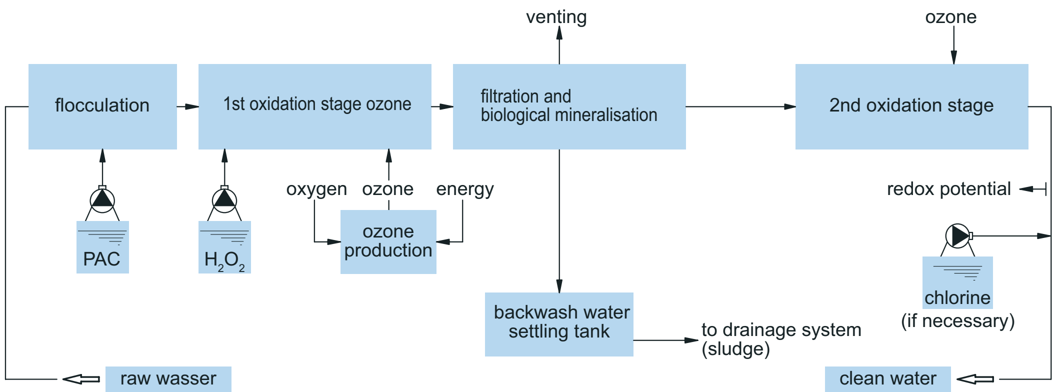


Area of use

- Spring water with a high level of turbidity and bacterial contamination
- Ground water with high concentrations of:
  - Iron
  - Manganese
  - Arsenic
  - Hydrogen sulfide
  - Ammonium (nitrification in the biologically active filter)
  - Nitrite

Process with advanced oxidation process (AOP)

The process with an advanced oxidation stage is necessary for the treatment raw water contaminated by residues of chlorinated hydrocarbon substances (CHC) or pesticides.



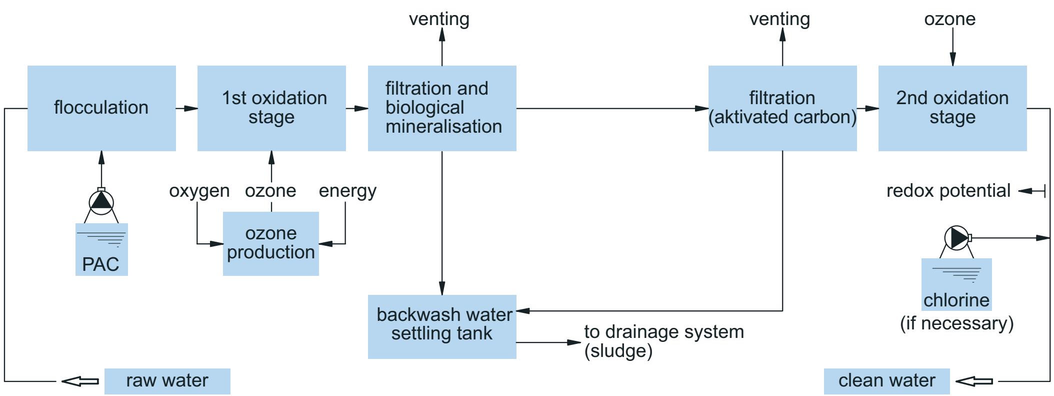
Area of use

Groundwater contaminated by human sources, e.g.

- water contaminated with pesticides
- water contaminated with chlorinated hydrocarbon substances (CHC)

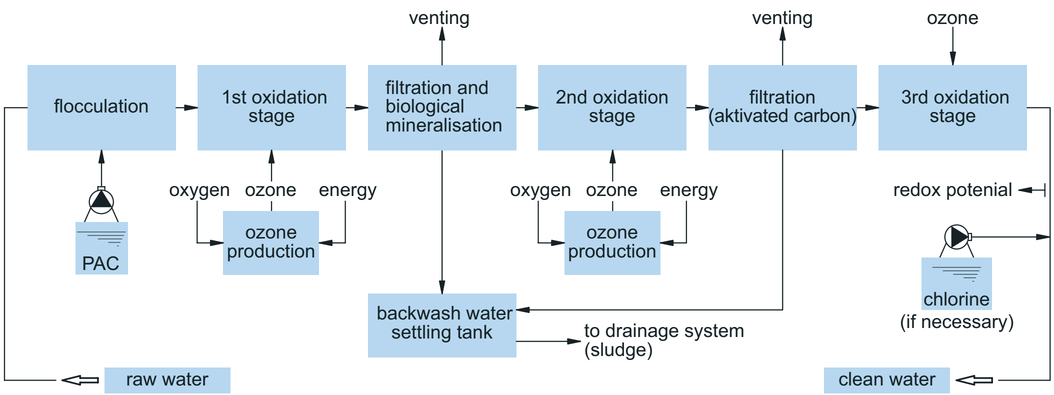
AOP Hydrogen peroxide (H_2O_2) is also added in the advanced oxidation process. The oxidation capacity is increased by the formation of hydroxyl radicals ($OH^•$). In this way, chemicals designed for long-term stability are broken down and opened up for biological mineralisation.
The subsequent biological filter stage mineralises the fragments and thereby minimizes the formation of metabolites.

Ozone biofiltration Ozone bio-filtration is used when there are greater humate concentrations (high colour and high DOC values).The activated carbon stage can be arranged in a filter with the filter stage.



Area of use
- Groundwater with no or insufficient groundwater protection
- Karst water
- Bank-filtered water
- Groundwater influenced by surface water
- Surface water from lakes

Process with triple oxidation The HYDROZON® process with triple oxidation and double filtration is used mainly for treating surface water and water contaminated by human sources.



Area of use
- Surface water from lakes and rivers
- Bank-filtered water from heavily contaminated water sources
- Thermal water with hydrogen sulfide, methane and other reduced substances

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