Industrial Gases for the Conditioning of Drinking Water

Drinking Water – Our Most Vital Nourishment

High quality drinking water is one of the essentials we require for living. However, low quality raw water has increasingly to be used for the production of drinking water.

Drinking water is subject to stringent statutory requirements. The Drinking Water Provisions and the EU Directives regarding Drinking Water Quality determine parameters for the quality of drinking water.

To ensure a high quality drinking water supply, the raw water, in most cases, has to be conditioned to comply with the statutory requirements. For that, industrial gases provide a variety of conditioning possibilities.

Particular problems in the conditioning of water for the beverage industry can also be successfully solved by the employment of industrial gases.

Apart from supplying the technical gases required for the drinking water conditioning, Linde also provides the necessary technology to control and regulate the gas injection process.

Reactor for rapid decarbonization

Applications for industrial gases for drinking water conditioning

	O_2	O_3*	CO_2	H_2
Oxidation	●	●		
Disinfection		●		
Corrosion prevention	●		●	
Hardening			●	
Decarbonization			●	
pH-adjustment			●	
O_2-reduction				●
Nitrate reduction			●	●

* Made from O_2

Water tower for testing and optimizing gas injection systems

Pumping station in a waterworks

Injection nozzle for carbon dioxide

Control room in a waterworks

Overflow with lance for carbon dioxide injection

Pressure filter in a waterworks

Oxygen – Essential for Our Drinking Water

A wide range of natural purification processes in water take place with the help of dissolved oxygen. Oxygen maintains and supports oxidation processes.

For the conditioning of drinking water and in distribution mains oxygen is consumed in chemical and biochemical transformations. The enrichment of raw water with oxygen is therefore the first step on the way to high quality drinking water.

In comparison to air, industrial oxygen achieves a 4.8 times higher saturation concentration as a result of its higher partial pressure. It is therefore possible to achieve high oxygen concentrations with only little technical effort.

$$c_s (O_2) = 4.8 \times c_s (\text{air})$$

At the same time, the dissolution of nitrogen from air in the water is prevented. Thus, the performance of filter systems can be improved and consumers no longer face the problem of undesired turbidity of the water due to nitrogen degassing.

Classical applications for industrial oxygen:

- Oxidation of
  - Iron(II) ions
  - Manganese(II) ions
  - Ammonium ions
  - Methane
  - Hydrogen sulphide
  - etc.
- Corrosion prevention

Pressure filter for the removal of iron and manganese

Oxidative conditioning of drinking water

According to the Drinking Water Provisions, the following maximum concentrations for the heavy metal ions iron (II) and manganese as well as for hygienically unsound ammonium ions have to be observed:

Iron (II):	0.20	mg/l
Manganese (II):	0.05	mg/l
Ammonium:	0.50	mg/l

Applying oxygen, these water substances are transformed either into precipitable and filterable substances or into harmless substances.

Specific oxygen demand for the oxidation of

1 g iron(II):	0.149 g O_2
1 g manganese(II):	0.299 g O_2
1 g ammonium:	3.569 g O_2

Complex-bound iron (II) and manganese (II) ions as well as other scarcely degradable substances react with ozone to form biologically degradable substances.The production of ozone from oxygen instead of air offers substantially higher economic advantages.

Corrosion prevention

A lack of oxygen often causes corrosion on metallic materials in pipelines of the public water supply mains.

An oxygen concentration of at least 6 mg/l in pure water is, among other criteria, a major prerequisite for the formation and maintenance of a lime-rust coating in pipeline systems.

Advantages resulting from the use of industrial oxygen:

- Enhanced quality of the pure water
- Improved taste
- Increased performance of the filter system
- Corrosion prevention
- Prevention of nitrogen degassing
- Prevention of CO_2- losses

Oxygen injection device SOLVOX®-D (p > 6 bar gauge)

Linde SOLVOX® process

The dissolution of oxygen with the Linde SOLVOX® processes depends on the actual situation. Using nozzles or reactors, oxygen can be dissolved either directly in the raw water line upstream the filtration system or prior to the delivery to the consumer.

Existing oxidizers operated with air can often be converted to oxygen operation.

SOLVOX® reactor for the oxygen dissolution in drinking water

Carbon Dioxide brings Drinking Water into Equilibrium

Carbon dioxide occurs on a large scale in natural water, but not only as dissolved gas. In fact an equilibrium is formed between bound and dissolved carbon dioxide.

Carbon dioxide appears in water in the form of dissolved CO_2 molecules as well as in the form of hydrogen carbonate ions (HCO_3^-) and carbonate ions (CO_3^{2-}). The various proportions of the forms depend on the pH value.

pH < 4.3

$H_2CO_3 \rightleftarrows CO_2 + H_2O$

4.3 < pH < 8.2

$H_2CO_3 + H_2O \rightleftarrows HCO_3^- + H_3O^+$

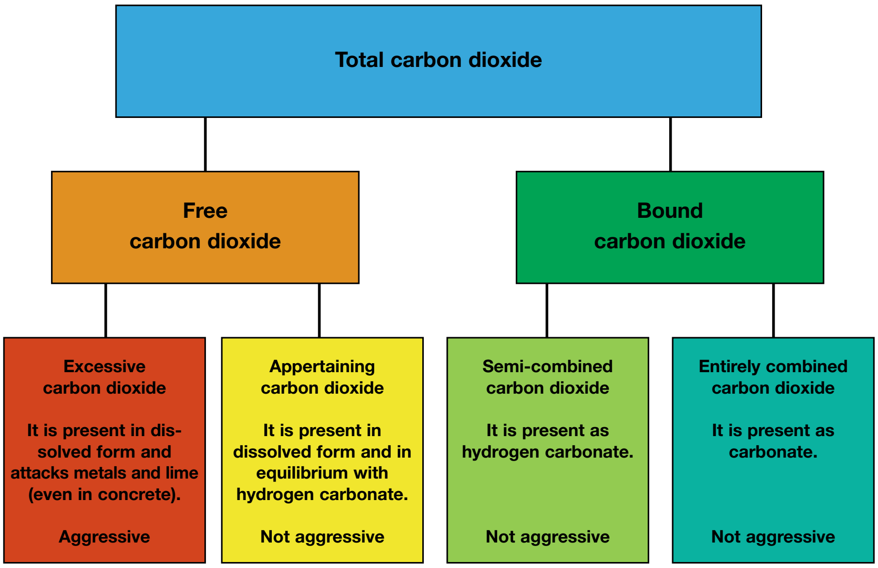
pH > 8.2

$HCO_3^- + H_2O \rightleftarrows CO_3^{2-} + H_3O^+$

At a pH of 8.2 the carbon dioxide appears almost completely in the form of hydrogen carbonate.

Carbonate ions only occur in mentionable quantities at a pH higher than 8.2.

The alkaline earth ion, calcium, plays an important role as a hardener in water. A common problem is, however, the precipitation of calcium carbonate (calcite).



Forms of carbon dioxide in water

Water hardness

The hardness of water is determined by the quantity of dissolved calcium and magnesium ions. Very soft water, such as water from dam reservoirs with a hardness of less than 0.5 mmol calcium per litre, does not precipitate calcium carbonate. Though, a slight precipitation is necessary to form and maintain a lime-rust coating in pipelines. To prevent corrosion, the hardness of water from dam reservoirs is therefore often increased to a level of at least 1.0 mmol calcium per litre.

The carbonate balance

Water is in a carbonate balance if it neither dissolves nor precipitates calcium carbonate. In this case, the saturation index for calcite is zero. If more carbon dioxide has been dissolved than is actually required to achieve the balance, the water contains aggressive carbon dioxide. This attacks pipelines and causes corrosion damage in concrete and metal pipes. If less carbon dioxide has been dissolved than required, the water precipitates lime. Thus, pipelines and fittings become calcified.

Applications of carbon dioxide:

1. Hardening of water

In case of insufficient hardness, carbon dioxide and lime water are used to adjust the desired hardness.

2. Utilization after a rapid decarbonization

After a rapid decarbonization with lime milk, the water often precipitates limestone. The balance can be restored by adding small amounts of carbon dioxide.

3. Utilization in limestone-precipitating water

The application of carbon dioxide is useful in case of limestone precipitation in raw water. Thus, the carbonate balance can be restored by adding carbon dioxide.

The adjustment of the carbonate balance and the desired water hardness by using lime and carbon dioxide is advantageous for both, operators of waterworks and consumers.

Advantages resulting from the utilization of carbon dioxide:

- Accurate adjustment of the desired water hardness
- Improved taste
- Prevention of limestone formation
- Prevention of corrosion in pipeline mains

Linde SOLVOCARB® for the effective dissolution of carbon dioxide

The Linde SOLVOCARB® process provides a series of well tested injection and dosage systems which effectively dissolve carbon dioxide in water.

Linde SOLVOCARB® reactors

Control cabinet for the dosage of carbon dioxide

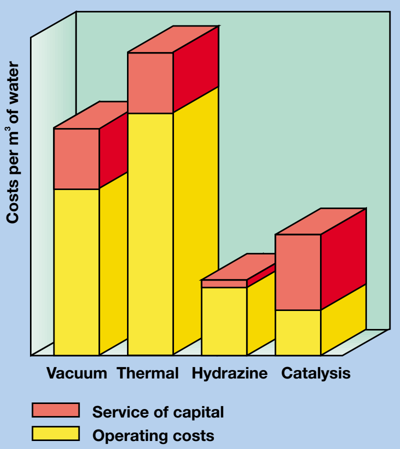
Hydrogen –
for Healthy Drinking Water

Removal of oxidizing substances with hydrogen

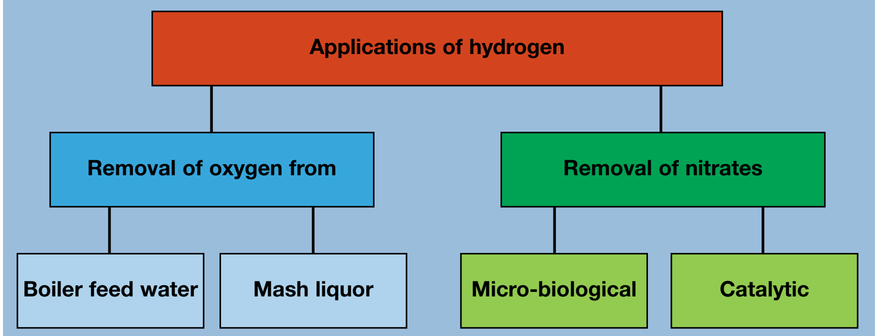
In certain cases, oxidizing constituents are undesirable in natural water. This particularly applies to nitrates which filtrate into the ground water after the use of fertilizers and through biological oxidation (nitrification) of ammonium in the soil. Dissolved oxygen can also be undesirable, particularly in mash liquor and dilution water for the beverage industry.

For these cases, reductive conditioning with hydrogen, whereby nitrate is converted into nitrogen and water respectively oxygen into water, has proved to be effective. The following processes for the removal of dissolved nitrate and oxygen from raw water have already been proved to be successful in industrial applications:

Comparison of costs for various degassing processes



Hydrogen applications for water conditioning



Autotrophic denitrification

Nitrate is a common ground water content, but its concentration in drinking water is limited to a maximum of 50 mg/l. Since this concentration is often exceeded in ground water, a reduction of the nitrate content is required.

For this, autotrophic micro-organisms which decompose nitrate while consuming hydrogen and carbon dioxide offer an effective solution.

An additional dosage of carbon dioxide covers the nutrient requirements of the micro-organisms and, at the same time, neutralizes the alkalinity which results from the decomposition process.

Catalytic denitrification

The removal of nitrate can also be carried out in a catalytic process with hydrogen.

In this case, a catalyst is used which guides the reaction precisely up to the level of elementary nitrogen, which then escapes in the gaseous form.

Features of autotrophic as well as catalytic denitrification:

- Quantitative reduction of nitrate
- Low nitrite formation
- Low ammonification
- No addition of chemicals
- Low afflux of wastewater
- Low energy consumption

Water conditioning for the production of beverages

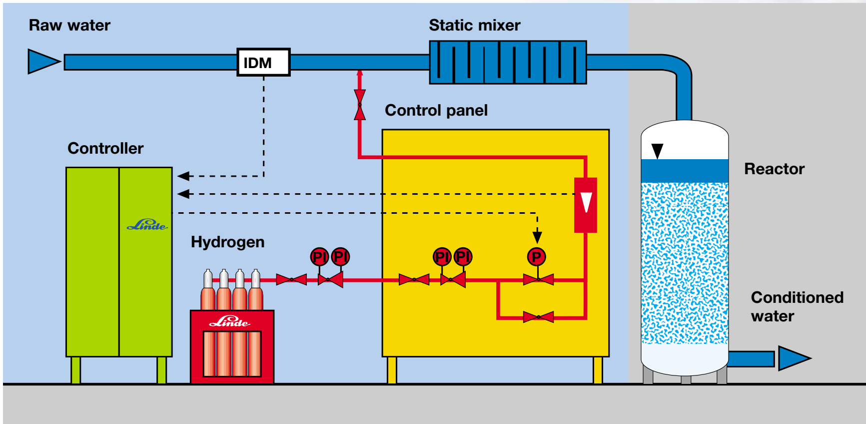
Oxygen-free water is required in the beverage industry for the high gravity brewing process and as dilution water for the production of soft drinks. Thus, it prevents oxidative changes to the colour and flavour.

Oxygen can advantageously be removed by catalytic conversion. This reaction takes place at ambient temperature on a palladium catalyst in the water phase.

In comparison to physical processes such as vacuum or thermal degassing, the above mentioned process offers the following advantages.

Advantages of catalytic conversion with hydrogen:

- Lower energy consumption
- Lower operating costs
- High operational reliability



SOLVOGEN® process flowsheet

Linde SOLVOGEN® process

The accurate dosage of the required hydrogen quantity into the raw water flow is extremely important. For this purpose, Linde developed the SOLVOGEN® process which allows the accurate dosage of the required hydrogen quantity.

Hydrogen injection is either solely controlled by the flow rate of raw water or by additional command variables such as the oxygen concentration in the raw water, the residual oxygen content or the hydrogen concentration.

In addition to hydrogen and the relevant supply equipment, Linde also supplies the control equipment in explosion-proof design and the necessary injection equipment to disperse the required hydrogen in the water phase.

Other fields of application for the Linde SOLVOGEN® process:

- Boiler feed water degassing
- Conditioning of water in heating circulation systems
- Conditioning of process water in the chemical industry

Hydrogen tank

Linde Gas Injection Systems – Economical and Flexible

The gas injection systems developed by Linde

- SOLVOX® for oxygen,
- SOLVOCARB® for carbon dioxide,
- SOLVOGEN® for hydrogen

ensure optimal gas utilization if they are used under their designated conditions.

Reactor

Stainless steel reactors are available as standard in sizes from 15 to 1000 m^3/h of water. Loop-type reactors made of PVC for water flow rates of 3 to 50 m^3/h can be supplied specifically for the injection of carbon dioxide.

Advantages of the reactors:

- Quantitative utilization of gas
- High gas concentrations in the water
- Inline- or by-pass mode possible

Oxygen injection device (p < 6 bar gauge)

Oxygen measurement and control panel

Nozzle

Injection systems with nozzles are available in two designs: for water pressures below 6 bar and over 6 bar. Depending on the application, various nozzle ends may be used. To support the gas injection, a static mixer may be installed after the gas dosage point.

Advantages of the nozzles:

- Gas injection without external energy supply
- Low investment costs
- Easy installation and maintenance

Dosage

In cooperation with the customer we develop the most suitable gas dosage system for each application. For less demanding processes, this is a defined gas flow. For more sophisticated applications the gas flow is controlled either according to the water flow and the concentration or according to the pH value. The dosage can be carried out in batches or continuously.

The right injection system for all gas types

	O_2	CO_2	H_2
Stainless steel reactor	●	●	●
PVC reactor		●	
Spherical-head nozzle	●	●	
Sintered metal nozzle		●	●

Service from a Single Source: From the Completion of Trials to Gas Supply

Linde Applications and Engineering Centre: Expertise for our customers

The manifold application possibilities for industrial gases in environmental engineering are the result of consistent research and development. Highly qualified scientists, engineers and technicians develop particular and sophisticated solutions for our customers at our Applications and Engineering Centre.

Linde Industrial Gases is certified in accordance with DIN EN ISO 9001. Consequently, each injection system and each control unit is tested according to stringent quality standards prior to its delivery to our customers.

Gas supply: Safe, reliable and practical

Our all-over network of production and distribution sites guarantees rapid, safe and economical gas supplies to our customers.

All tank systems and containers for gas supplies can be rented from and maintained by Linde. Punctual supplies are guaranteed as a result of our large road tanker fleet.

Oxygen supply

Cryogenic liquefied oxygen is supplied by road tankers and stored in vacuum-insulated tank systems. The liquid oxygen is converted into its gaseous phase on site using air-heated evaporators which require no external energy supply.

For smaller gas quantities, we recommend the use of gaseous oxygen from cylinder bundles or individual cylinders.

Carbon dioxide supply

Carbon dioxide is also supplied in road tankers in liquefied form and stored in tank systems. The liquid carbon dioxide is converted into its gaseous phase on site using air-heated evaporators which require no external energy supply. For smaller gas quantities, carbon dioxide in the gaseous form is available from cylinder bundles or individual cylinders.

Hydrogen supply

Hydrogen is supplied either gaseous in steel cylinders (cylinder bundles) or as a cryogenic liquid by road tanker delivery. It is stored at the customer's site in cylinders, specific pressure vessels or in vacuum-insulated tanks.

Analysis in our Linde laboratory

Carbon dioxide tank

Hydrogen trailer

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