

THE LINDE GROUP

Linde

Pure Water Knowledge.

Gases and application technologies
for water treatment.

Drinking Water

Industrial Wastewater

Municipal Wastewater

Process Water

Surface Water

Introduction. Addressing the needs of the water treatment industry.

Challenges in the water treatment industry

Water is one of the most valuable resources on Earth. All living things depend on this precious commodity, yet access to clean, safe water is becoming increasingly difficult in many parts of the world. As global water consumption increases, so too do the challenges in supplying clean water. While many regions struggle with limited amounts of fresh water, others need to handle large volumes of human and industrial contaminated wastewater inflows, which require proper treatment in order to be reused or returned to groundwater flows.

Plant operators around the globe need to find ways to manage the wastewater from rapidly growing megacities. Here, demand is outstripping the original planned capacities, and the sometimes antiquated water treatment infrastructure requires significant investment just to keep operating. The increase in complexity of micro-pollutants that remain untreated by conventional wastewater techniques pushes the industry to look continuously for alternative technologies.

In addition, governments are increasingly creating new, stricter environmental regulations to ensure wastewater is treated to the highest standards. Given the impact of water hygiene on human and animal health, safety is the number one aim and priority of these tighter legislative controls.

Innovative solutions for water treatment

This publication covers the benefits derived from the use of gases such as oxygen, carbon dioxide and ozone in water treatment processes. With over 30 years of experience in the field, we have been working together with plant operators worldwide to overcome critical challenges such as pH control, permanent and seasonal capacity increase, odour control and micro-pollutants management.

Our customers can count on:

- Reliable supply of industrial gases
- Innovative and intelligent dosing systems for both oxygen and carbon dioxide
- Cost-effective on-site supply and recycling systems for oxygen used in ozone production
- Excellent service capabilities as support during installation and maintenance downtime
- Access to a state-of-the-art water lab for sampling and testing
- Best practices from over 500 installations globally, covering industrial and municipal wastewater, drinking water, process water and surface water



Pure oxygen. Get the most out of your plant.

Why use oxygen instead of air?

Oxygen is more effective than air in supporting the natural treatment of water. It creates optimal aerobic conditions for successful biological treatment and supports biological nutrient removal.

Several of the key problems operators experience in municipal and industrial biological aerobic wastewater treatment can be fully solved or substantially reduced by the systematic addition of oxygen to the water treatment process.

By diffusing just the right amount of oxygen into water you can:

- cover scheduled aeration **equipment maintenance**
- provide **additional capacity** when existing aeration is limited
- cover **production peaks**
- **avoid process problems** such as excessive foaming or creation of aerosols and mists
- **eliminate odours**
- **reduce surplus sludge** volumes
- **avoid corrosion** in pressurised transfer pipes
- **reduce CAPEX** for mid- and long-term capacity increase
- secure **additional oxygen demand** during biological nitrogen removal

“We have used oxygen in our pre-treatment stage for many years to reduce the amounts of VFAs and COD, which could overload our main wastewater treatment plant. When Linde experts made us aware of their new SOLVOX® mobile, we could see that it was a simple and flexible solution that could be readily used in our pre-treatment lagoon. Installation was quick and simple, we received great support from Linde experts and it is very easy to operate. We are happy that Linde also thinks of the reduction of costs for the customer, both in the amount of required oxygen and in the power consumption of the oxygen dosing system.”



Aerobic treatment with oxygen. Flexible and efficient aeration technologies.

Based on decades of experience, we developed a complete portfolio of oxygenation equipment to meet customers' aeration and mixing needs. Our turnkey solutions include gas dosing equipment, electrical control systems and the full support of our engineers for installation advice, supervision and commissioning services. Our portfolio is compatible with existing equipment and therefore can be used to complement systems already in use. From temporary to permanent solutions and from low to high oxygen demand, you can count on us to find the best option to address your specific challenges.



SOLVOX® mobile

Coping with load peaks and maintenance downtime

SOLVOX mobile is our new technology specifically developed for operators of small- to medium-sized industrial wastewater treatment plants that need to cope with peak loads and downtime during aeration equipment maintenance. This lightweight and compact unit can be easily installed, with no need to halt operation. The free-floating design means it is suited to basins with challenging shapes and lagoons with non-load-bearing linings. Benefits include low energy consumption and a modular concept to give operators more flexibility for additional mixing power.



Easy installation of SOLVOX mobile



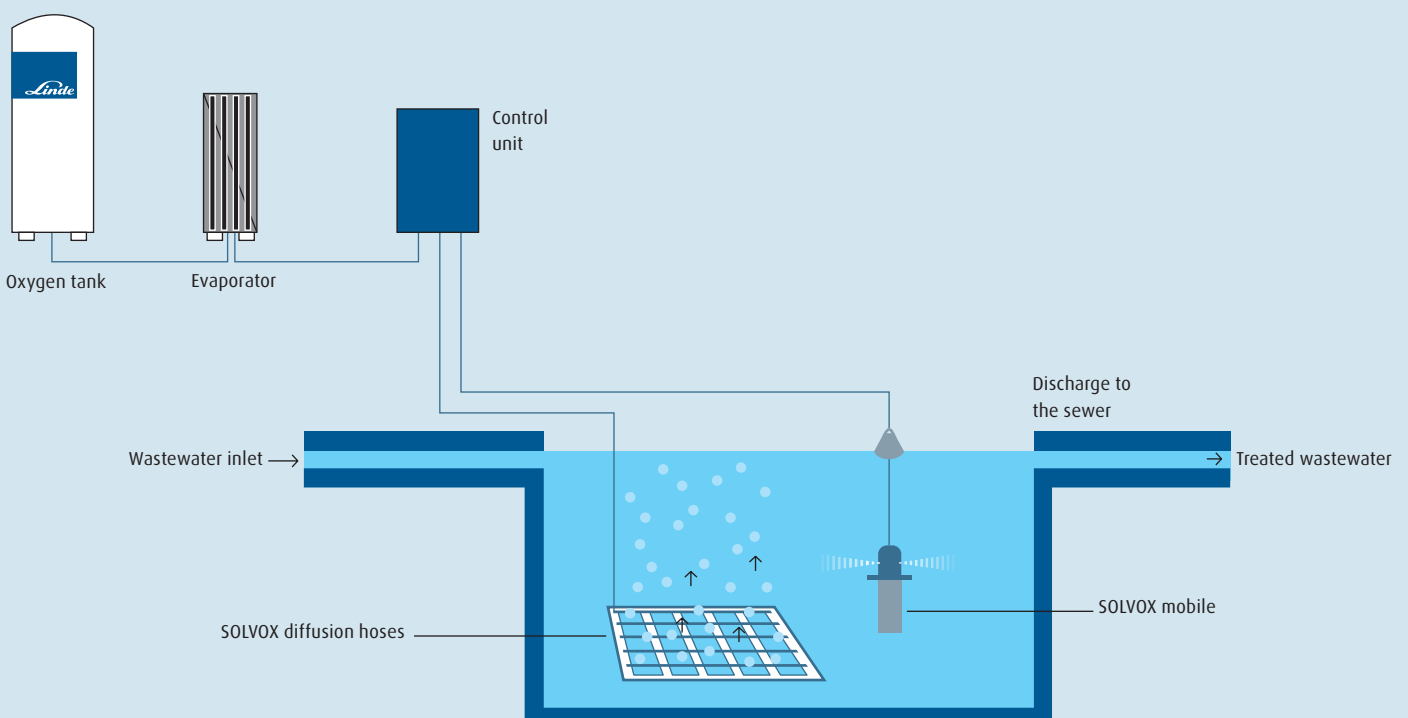
SOLVOX mobile flow skid

"It has been a rewarding experience over the past decade to bring customers and the best minds of different Linde entities together to create new solutions which fully satisfy our customers beyond their expectations. One very nice example was a customer at a show literally hugging one of our SOLVOX products saying: 'I want to have it'."

Dr. Stefan Dullstein, Sr. Process & Business Development Manager, Linde

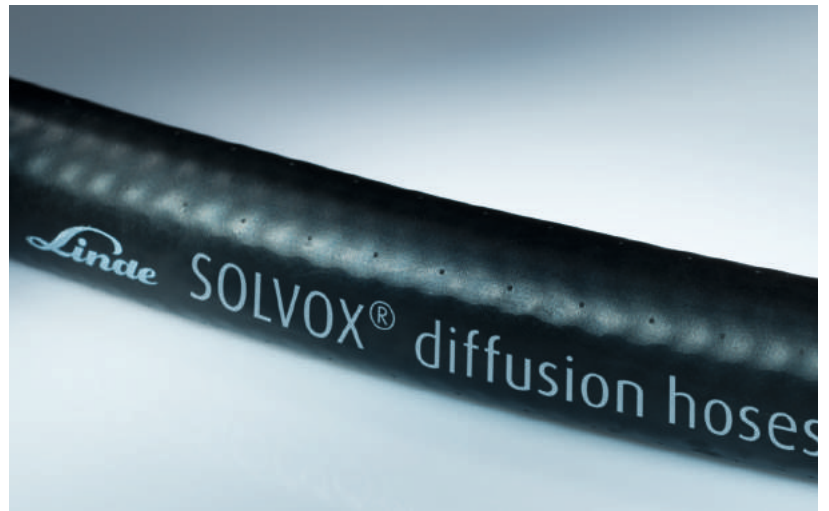


SOLVOX® installation diagram



SOLVOX® diffusion hoses

Flexible and low-maintenance solution for deep tanks
 Requiring no external power, the diffusion hoses can be easily adapted to any tank or basin shape and remain clog-free even after long periods of non-operation. Suitable for both oxygen and ozone, these hoses provide a cost-effective solution for deep tanks.



SOLVOX® inline injector

Increasing the service life of pressurised pipes
 The injection of oxygen directly into pressurised wastewater transfer pipes has proved to be effective in preventing the sulfurous corrosion and offensive odours that are usually caused by anaerobic processes. This technology has no power requirements and contributes to the partial treatment of incoming wastewater.

SOLVOX® reactor

Low-turbulence diffusion for oxygenation of raw water
 Available in eight different capacities, the pressurised reactor can be integrated into the main or bypass flow. Because the oxygen is added through the reactor, very low agitation is created. This technology is ideal when space is limited and the pipework run is short since it allows for optimal mass transfer even when retention is suboptimal.



“One of the things I value most is earning the trust of our customers. During the last 25 years I have had the privilege of serving more than 100 customers: Linde works hard to live up to the expectations of providing great service, on time and at a fair price. That is part of our DNA.”

Darren Gurney, Sr. Process & Business Development Manager, Linde



Aerobic treatment with oxygen

Linde technologies – technical characteristics overview

Linde technology	Process application	Water depth m ft	Mixing demand	Installation type	Oxygen flow rate kg/h lb/h	Treated water flow rate m ³ /h '000 US gal/h	Oxygen transfer rate kg/kw lb/hp
SOLVOX mobile	Ind. Wwt.	from 3 to 15 >10 to 49	Moderate	Submerged: floating or fixed	10 to 25 22 to 55	N/A	4.5 7.4
SOLVOX diffusion hoses	Mun. Wwt, Ind. Wwt., Surface Water	from 4 to 15 13 to 49	Needs external mixer	Submerged: fixed	10 to 35 (per 40 m) 22 to 77 (per 130 ft)	N/A	N/A
SOLVOX reactor	Drinking Water, Process Water	N/A	Low	Inline or side-stream	2 to 110 4.4 to 242	240 to 1.32 x 10 ⁴ 63 to 3490	N/A
SOLVOX inline injector	Mun. Wwt., Ind. Wwt., Process Water, Drinking Water	N/A	N/A	Inline or side-stream	30 66	900 to 1500 238 to 396	N/A

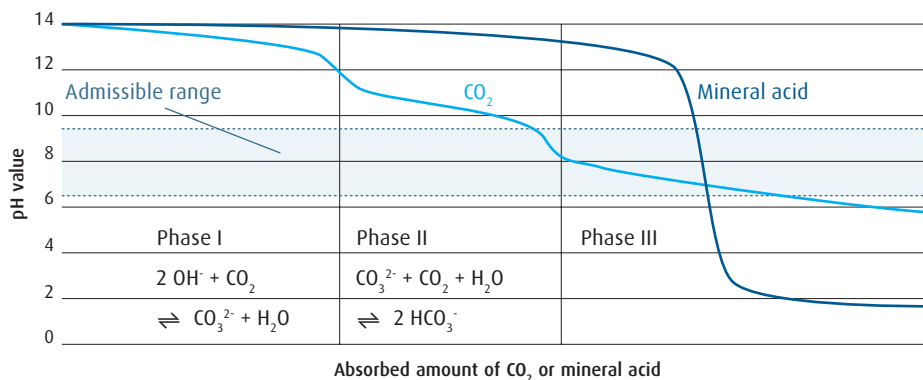
Carbon dioxide. Replacing mineral acids for safe and precise handling.

When dissolved in water, carbon dioxide forms carbonic acid, an effective neutralisation agent. A fundamental advantage of carbonic acid is the almost flat gradient of its neutralisation curve, which allows the desired pH value to be easily and precisely adjusted even at variable raw water parameters, without the danger of over-acidification.

Compared to mineral acids, carbon dioxide has many advantages:

- It is **safer to handle** and is a **highly effective** alternative to highly corrosive mineral acids
- It allows you to **precisely control pH**
- By using CO₂, you can **avoid excessive acidification** of wastewater due to its self-buffering capacity
- **It reduces maintenance costs**, since there is no corrosion damage to plant fabric or pipework
- **It preserves water characteristics** by maintaining water alkalinity and preventing the accumulation of unwanted anions such as chlorides or sulfates
- It has a direct impact on CAPEX and OPEX: CO₂ is safe to handle and thus allows savings in safety equipment and **bypasses the need for chemical containment or bunding**. Since it is non-corrosive, plant **maintenance costs are significantly reduced**

Neutralisation of sodium hydroxide solution with CO₂ and with mineral acid



Neutralisation with CO₂. Competitive solutions for pH control.

The SOLVOCARB® portfolio includes reliable gas supply schemes and efficient injection equipment to add carbon dioxide to the water. Our team of experienced engineers will assist you to make sure that all processes run smoothly, from installation to operation.

We will provide you with fully tested and competitively priced metering and dissolving systems for carbon dioxide. The application equipment of the SOLVOCARB family can be applied flexibly in an inline or bypass operation, thus offering a broad range of solutions for specific customer requirements.



SOLVOCARB® mobile

Safe, cost-efficient and ready-to-use SOLVOCARB mobile is a Linde technology specifically developed to support operators of small- and medium-sized plants looking for a safe and accurate pH control alternative to mineral acids. It is designed for easy installation and is suited to basins with challenging shapes as it is free-floating. Highlights include minimum power consumption and ease of maintenance, making this a low-CAPEX and low-OPEX solution.

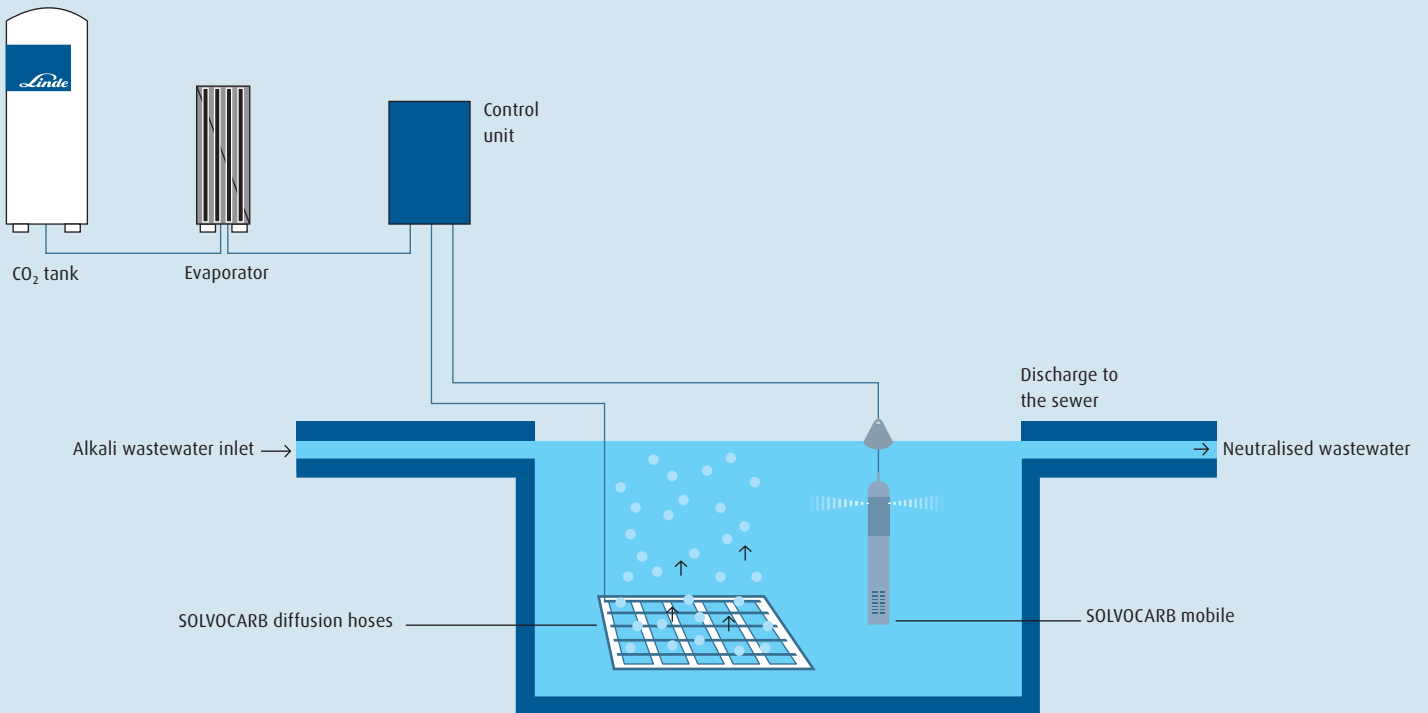


SOLVOCARB® venturi

Superior CO₂ mass transfer efficiency

The low pressure drop venturi dissolver can be used in conjunction with pumped or gravity-fed systems to provide high rates of mass transfer coupled with superior dissolution efficiency. Suitable for fresh water or water with a high level of total dissolved solids (TDS), it is ideal for a wide range of water treatment applications where CO₂ needs to be dissolved and accurate pH control is essential. This technology is easily retrofitted to existing hydraulic systems and ensures a consistent performance while requiring low maintenance.

SOLVOCARB® installation diagram



SOLVOCARB® reactor

Maximum performance for raw water treatment

This technology, suitable for drinking water applications, has proven to be an extremely efficient method for adding dissolved carbon dioxide to re-mineralise, re-carbonate or control the pH of raw waters. Versatility is another key asset of the SOLVOCARB reactor. It can work within a wide range of temperatures, flow rates and pressures and is suited for inline or side-stream modes, either for internal or external use.



SOLVOCARB® diffusion hoses

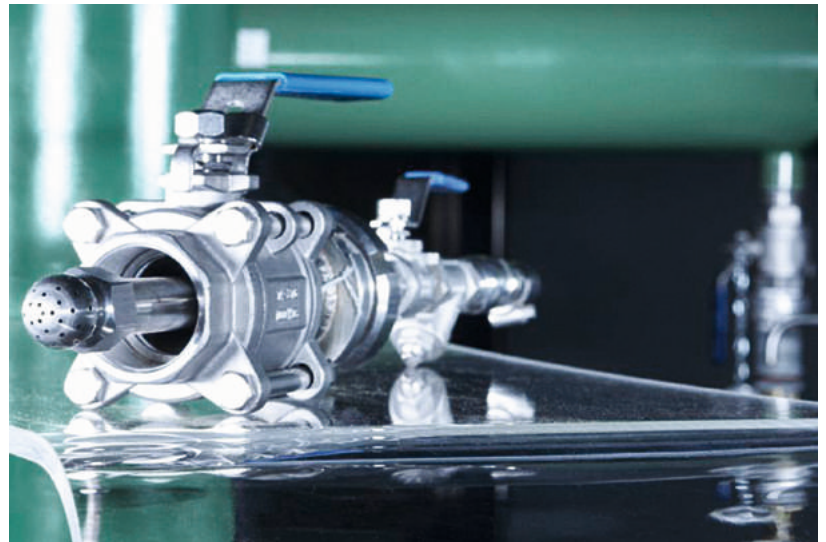
Flexible and low-maintenance solution for deep tanks

Designed for fast and easy installation even in operational tanks, the diffusion hoses will run clog-free for long periods of time without requiring maintenance or an external energy supply. When the hose is under pressure, the perforations expand to allow the passage of gas into wastewater in the form of fine bubbles and, when the pressure drops, the holes close up again. This cost-effective solution for deep tanks is ideal for both temporary and long-term use.

SOLVOCARB® inline injector

Maximum convenience with upstream neutralisation

Specifically developed for the injection of carbon dioxide into pressurised pipelines, the inline injector feeds the carbon dioxide directly into the raw water stream through a stainless steel nozzle. Due to the high solubility of CO₂ in water and fast reaction rates with alkaline water, the SOLVOCARB inline injector usually eliminates the need for a static mixer. It can be used with a side-stream recycle pump to treat in-batch or continuous flow-through configurations.



Neutralisation with CO₂

Linde technologies – technical characteristics overview

Linde technology	Process application	Water depth m ft	Mixing demand	Installation type	Carbon dioxide flow rate kg/h lb/h	Treated water flow rate, m ³ /h '000 US gal		CO ₂ mass transfer rate kg/kw lb/hp, operating at 2.0 bar
						Drinking Water	Wastewater	
SOLVOCARB mobile	Ind. Wwt., Process Water	> 2.5 > 8	Moderate	Submerged: floating or fixed	15 to 45 33 to 100	N/A	100 to 320 26 to 85	18 30
SOLVOCARB venturi	Mun. Wwt, Ind. Wwt, Drinking Water, Process Water	N/A	N/A	In-line or side-stream	10 to 400 22 to 100	1250 to 12 x 10 ³ 330 to 3170	70 to 2800 18 to 740	9 to 12 15 to 20
SOLVOCARB diffusion hoses	Ind. Wwt., Surface Water, Process Water	> 4 > 13	Needs external mixer	Submerged: fixed	20 to 60 (per 40 m) 44 to 132 (per 131 ft)	N/A	140 to 430 37 to 114	N/A
SOLVOCARB reactor	Drinking Water, Process Water	N/A	N/A	In-line or side-stream	30 to 2000 66 to 4409	750 to 50 x 10 ³ 198 to 13209	N/A	25 40
SOLVOCARB in-line injector	Mun. Wwt., Ind. Wwt., Process Water, Drinking Water	N/A	N/A	In-line or side-stream	10 to 50 22 to 110	750 to 1250 198 to 330	70 to 350 18 to 92	N/A

SOLVOCARB venturi: Stoichiometric neutralisation of unbuffered NaOH solution from pH 11.5 to pH 8.5, CO₂ per m³ = 0.14 kg/m³ | CO₂ per '000 US gal = 1.17 lb/'000 US gal
 SOLVOCARB reactor: Drinking water based on 20°C and 4.0 bar operating pressure | 68°F and 58 psi operating pressure

Pure oxygen for ozone generation. Treating water with one of the most powerful oxidants.

Ozone has been used in water treatment for a long time to get rid of contaminants, reduce micro-pollutants in drinking water and for treating industrial wastewater with a high chemical oxygen demand (COD) as found in the textile, pharmaceutical and specialty chemicals industries.

Recently, more and more countries have been introducing regulations for the residual micro-pollutants in treated wastewater after conventional municipal biological treatment. Various Advanced Oxidation Process treatment trains have been tested for this purpose, and ozone has been proven to be very effective in dealing with these compounds.

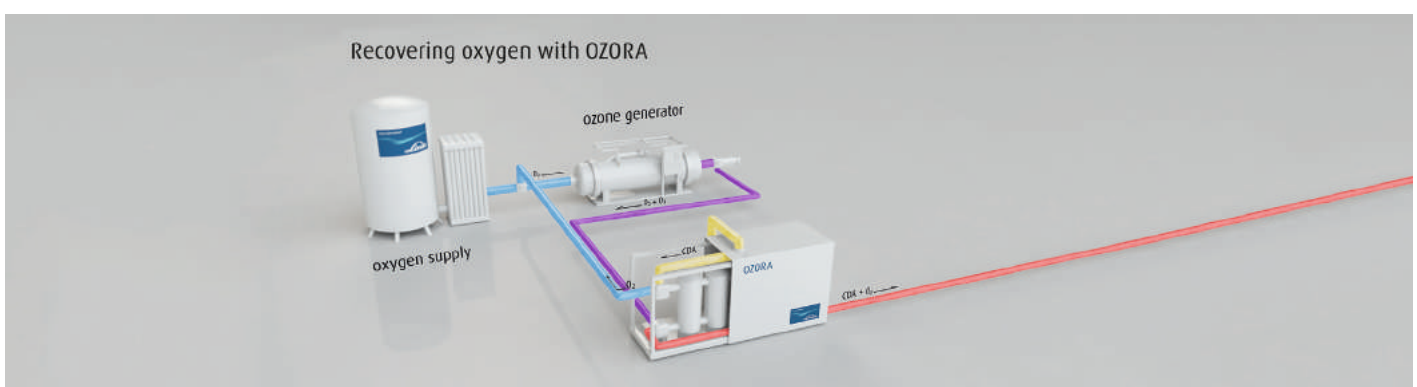
In the corona-discharge production process, ozone is created by an electrical discharge to ambient air or to highly concentrated oxygen.

When using pure oxygen instead of ambient air for the production of ozone, the following advantages arise:

- Higher ozone production
- Smaller footprint
- No pre-treatment of feed gas required

An overview of our oxygen supply modes can be found in the next section "Gas supply".

OZORA® oxygen recovery system. Bringing ozone production to new efficiency levels.



Up to 90% of oxygen loss in conventional ozone generation

During the ozone generation process, only a small part of the oxygen is actually converted to ozone. The remaining unconverted oxygen is ultimately vented.

OZORA® recovers oxygen before it is lost

With OZORA, you can recycle and reuse unconverted oxygen before it escapes. OZORA takes the oxygen/ozone mix from the ozone generator and separates the oxygen from the ozone. The oxygen is fed back into the generator while the ozone leaves OZORA so that it can be used for its end purpose.

Recover up to 60% of oxygen

Our patented solution reduces oxygen consumption by up to 60%. It therefore considerably reduces your operating costs and brings your ozone production to new efficiency levels.

Gas supply. Precise, reliable and on time.

Oxygen supply

Liquid oxygen is delivered by our dedicated fleet of cryogenic tankers into vacuum-insulated bulk storage vessels that we usually own and maintain on customer premises. The stored liquid is controlled at the required pressure by means of an automated regulation system. When the gaseous oxygen is required, the liquid is vaporised and delivered as a gas along the supply pipe.

With our ECOVAR® on-site supply solutions, we ensure a continuous, monitored and flexible gas supply directly on the customer's site. Our oxygen generation plants extract oxygen by means of adsorption, combining standardised components which are cost-efficiently adapted to the specific on-site demands.

Carbon dioxide supply

Small quantities of carbon dioxide are supplied in cylinders or cylinder bundles. Larger quantities of carbon dioxide are stored in vacuum-insulated vessels. For this purpose, liquid carbon dioxide is supplied in special road tankers and then transferred to the storage tanks on site. Handling CO₂ is also easy. In the case of vacuum-insulated tanks, an evaporator converts liquid carbon dioxide into its gaseous phase. With high-pressure tanks, the heat required to evaporate the carbon dioxide is applied via the tank wall. A level indicator on the storage tank indicates the daily consumption of carbon dioxide so plant managers can order a refill in due time.

Our company

100+ We serve our customers in over 100 countries worldwide

600+ air separation, hydrogen and CO₂ plants are operated by Linde

55 million t annual oxygen production capacity in Linde's air separation units installed since 2010

+10,000 trucks



Dedication to service and innovation. The customer is at the centre of everything we do.



“After 20 years serving Linde customers in this industry, one would expect that I would say: “been there, done that”. In the water treatment world it is not like that at all: new challenges are constantly coming up and I get to partner up with long-standing customers and with some of the greatest minds at Linde to find the best solution. This constant drive towards cutting-edge innovation, along with the relationships I have developed with colleagues and customers, gives me renewed energy levels when going to work every day.”

Stefanie Bland, Application Engineer, Linde



End-to-end service offering

Proof-of-concept trials at our water treatment laboratories is just one building block in our end-to-end service offering. We support our customers at every step of the way – from the initial assessment to the installation of a technology and gas supply scheme that is tailored to individual needs.

Specific services include:

- Troubleshooting
- Short-term and temporary supply of dosing and flow-control equipment
- Consultancy on the appropriate O₂/CO₂ flow to reach your desired treatment results
- Sizing, installation and maintenance of both the gas supply system as well as the dosing and flow-control system
- Comprehensive training on the equipment and gas handling



To provide the best service, we have local teams in more than 100 countries, dedicated to meeting each market's needs by combining the hands-on insights of a regional team with the know-how and reach of a global organisation. Our water treatment professionals receive regular training, and our teams partner with other industry players and research hubs to ensure we understand what is truly relevant for plant operators and remain at the forefront of advances in technology.

Customer-inspired culture of innovation

As a technology and innovation leader, we have a proven track record in the development and delivery of cutting-edge water treatment solutions. Our aim is to add value to our customers' business by solving concrete operational challenges. To ensure that our research work is guided by real-world needs, we work in close partnership with our customers, other industry players and research institutes.

At the heart of our research and development work lies our network of labs. At three water treatment laboratories around the world, we test and validate new products and processes under realistic conditions.

Recent examples of customer-inspired developments include OZORA, our oxygen recovery system for new-found levels of efficiency in ozone production, and SOLVOX mobile for uninterrupted oxygen supply during production peaks and maintenance downtime.

Customers can also visit our labs to watch live demos of our various application technologies. We run trials and simulations so customers can evaluate the impact of our gas-enabled solutions and select the treatment train best suited to their needs.



At our water treatment laboratories in Munich (Germany), Aalesund (Norway) and Shanghai (China), our customers can experience our technology innovations first-hand.

"Many of our innovations were sparked by our observation of a specific customer's problem. Working together with my water treatment colleagues in Aalesund and Shanghai as well as my colleagues from Linde Engineering, we have created a fantastic network of experts and a powerful springboard to transform an idea into a value-adding solution."

Jesus Orts, Application Engineer, Linde





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