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Expert Insights from Linde.

Harnessing oxygen to boost performance in aerobic wastewater treatment plants.

Main drivers for oxygen-based aerobic treatment plus a real-life example from the chemical industry.

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Common drivers for permanent and seasonal increased capacity needs in wastewater treatment plants.

Industrial Manufacturing & Production wastewater treatment plants (WWTP) are under mounting pressure to process ever-larger quantities of wastewater to stricter standards while also contending with cost constraints.

Plant operators are challenged to maintain treatment throughput at reasonable cost even when the plant reaches design capacity. This challenge can be compounded by changes to production runs and formulation mixes, often requiring additional investment in order to maintain stable plant performance. However, extending plant capacity to maintain or increase throughput while handling a new mix is often prohibitively expensive.

Ever-tightening environmental legislation is another key driver for investment in existing wastewater treatment plants. In particular, Environmental Regulations are increasingly raising the quality standards of treated wastewater. It is widely accepted that industrial enterprises cannot willfully pollute natural water resources and, as part of their permit to operate, these companies must demonstrate that they are able to treat all their pollution streams to prevailing national regulatory standards.

Seasonal fluctuations in temperature can be another pressure point. As temperatures rise in the summer months, so too does the temperature of wastewater. Aerobic bacteria are more active in warmer waters, raising the oxygen demand for BOD (biochemical oxygen demand) treatment, coupled with the reduced solubility of oxygen. As a consequence, the level of dissolved oxygen (DO) in the aeration basin drops, potentially generating, if the drop in DO is severe enough, anoxic zones. These can lead to the formation of process upsets, such as poor settlement in the secondary clarifiers. In extreme cases, anaerobic activity increases, which, in turn, can lead to the production of malodorous gases, such as hydrogen sulphide, being released into the surrounding atmosphere. Plant odors can create community issues, and excessive BOD breakthrough and/or increases in final effluent suspended solids can create compliance problems or even result in fees or fines from water treatment authorities.

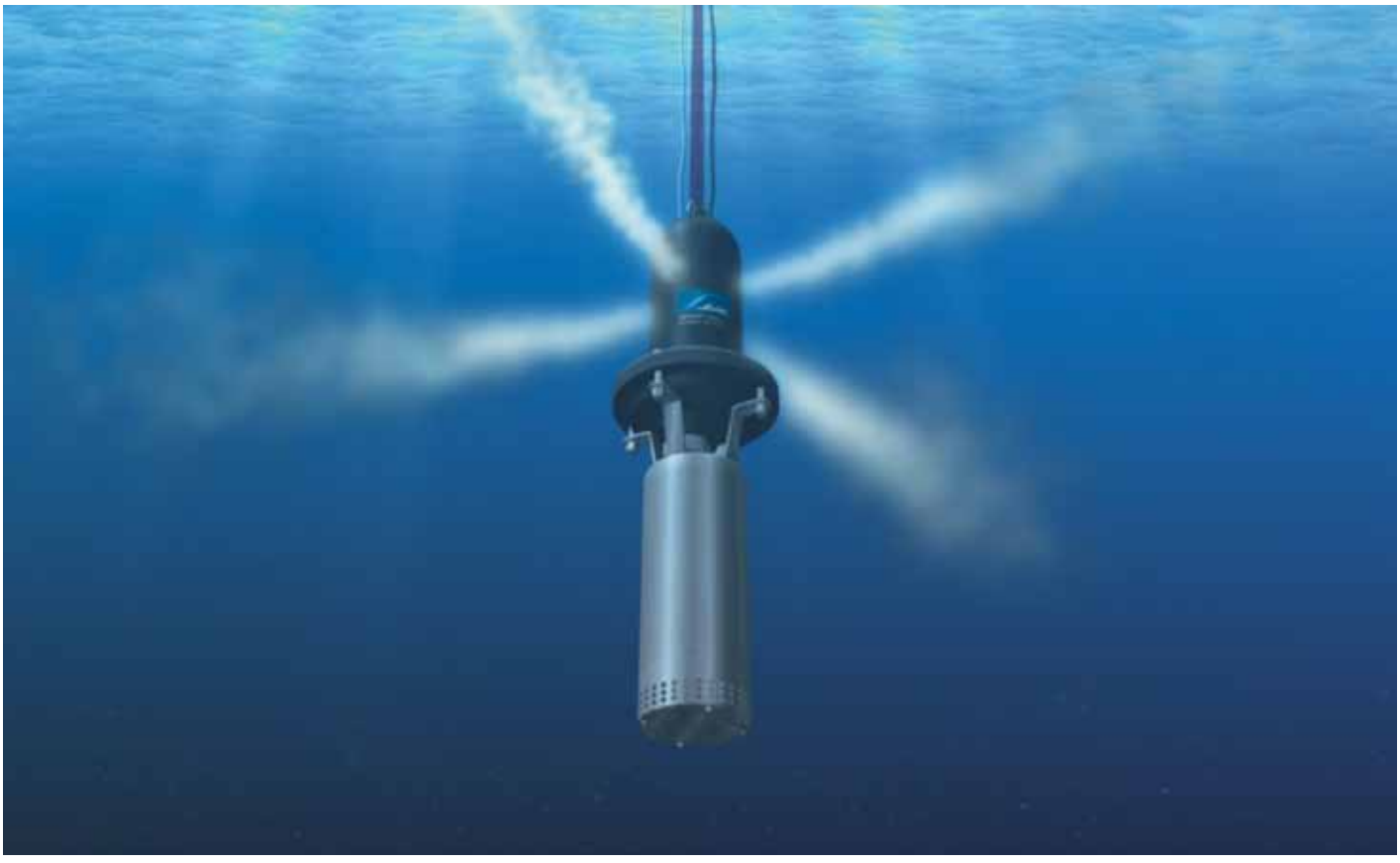
SOLVOX mobile installation at an industrial wastewater plant in the Netherlands.

Hence **many operators are looking to support increased seasonal oxygen demand more cost-effectively and efficiently than traditional aeration techniques,** which require energy-intensive air compression equipment. In addition, air only contains about 21% oxygen, making some conventional aeration techniques not particularly efficient as temperature increases or influent load varies.

Pure oxygen to support WWT plant upgrades.

In many cases, gas-enabled wastewater technologies are an effective way to balance conflicting cost, temporary capacity increase and compliance needs. **Innovative, gas-based solutions are often a low upfront investment solution to inject new life into existing assets and extend their longevity.** Often these technologies are also seen as a flexible way to bridge seasonal peaks in oxygen demand.

Experience has shown that the biological treatment of industrial wastewater can generally be significantly enhanced through a secondary treatment stage with dissolved oxygen levels above 2 mg/l. Our SOLVOX® family of oxygen dissolution technologies has been developed specifically for this application: **the high driving force of pure oxygen, additional process mixing and efficient oxygen transfer performance of the SOLVOX process results in excellent oxygen utilization performance and high transfer rates.** Assembly and installation requirements are minimal, with little or no construction work required. SOLVOX systems are ready to operate within a very short period of time and can also be installed in fully operational tanks, avoiding the cost and inconvenience associated with process shutdowns and drain downs.



Good mixing power and efficient oxygen transfer performance are essential to achieve homogeneous oxygen dissolution and to achieve ideal DO levels.

Case study: Meeting rising demand for dissolved oxygen in secondary-stage bioreactors.

In the following, we explain why one of Korea's largest chemical companies decided that oxygen-based aeration with SOLVOX was the best fit for its wastewater treatment challenges. The company manufactures a wide range of products from petrochemicals to high-value added intermediates and high-performance industrial materials.

Faced with an opportunity to increase production capacity, the manufacturer realized that the existing air-based plant was unable to meet future demand for dissolved oxygen in the secondary-stage bioreactors. Without an effective intervention strategy, the performance of this process step would have deteriorated, exposing the company to potential regulatory penalties for environmental infringements. This drop-off in performance would also have had an adverse effect on the downstream Fenton process tertiary treatment stage. In extreme cases of permit excursions, a company's license can be reviewed or even suspended until the required improvements have been put in place.

Challenges at this particular plant included high-salinity wastewater and operation at elevated temperatures in the secondary treatment stage – with values as high as 48 degrees Celsius recorded on occasion. Before undertaking an upgrade program, the manufacturer had to ensure that all new equipment could be installed without interfering with current operations.

The company approached Linde to explore solutions capable of increasing the oxygenation capacity of the existing WWT plant. Having examined the situation, Linde proposed its proprietary SOLVOX technology. Engineered for the even distribution and dispersion of oxygen-enriched water, SOLVOX mixing nozzles release very fine bubbles for optimum oxygen transfer. High-velocity jets re-circulate the oxygenated wastewater in the basin, thus ensuring continuously high oxygen utilization and efficiency rates. For security of operation, the injection of oxygen is automatically controlled by a signal from an installed dissolved oxygen probe via a transmitter located at each aeration basin, ensuring the process is kept within the recommended DO limit at all times.

The chemicals manufacturer decided to go with Linde's SOLVOX solution and noted an improvement in dissolved oxygen levels almost immediately. The company was able to reduce the demand on the existing aeration system by more than 40% and still achieve the desired performance within the secondary treatment stage.

Linde's intervention focused on the biological treatment phase, removing up to 70% of the pollution load, measured as Chemical Oxygen Demand (COD). After this secondary stage, the wastewater passes through several more stages of treatment; most notably a Fenton's Reagent process tertiary stage. Improving this secondary treatment stage reduces the burden on the downstream processes, as well as the total cost of treatment. The system implemented at the WWT plant in question achieved the required outcome without the need to physically build any additional volume capacity. Using the company's existing assets and retaining everything on the same footprint, a technologically advanced but straightforward upgrade was achieved in less than a week.

Linde's extensive range of SOLVOX process solutions are suited to a wide range of WWT plants with different operating conditions. Regardless of the individual treatment challenges, they can enhance existing aeration capabilities by introducing pure oxygen into wastewater activated sludge in a variety of ways. Adding pure oxygen with the SOLVOX process can also increase the performance of an existing plant during peak loads and maintenance of main equipment. Requiring a very low investment, it is an extremely flexible way for operators to adjust to seasonal peaks (i.e. rises in COD or BOD and warmer temperatures) and production campaign demands.

Proof of concept.

As this reference case shows, the controlled input of pure oxygen can contribute to the overall performance of WWT plants. It is a fast, flexible and efficient way for biological WWT plants that are struggling to maintain constant positive dissolved oxygen levels throughout the secondary treatment stage to overcome this problem.

Other oxygen-based solutions.

Oxygen is also applied in other highly effective WWT applications such as ozone processes, where it is used for the partial or complete oxidation of organic compounds present in industrial wastewater. Ozone is an unstable molecule which readily gives up one atom of oxygen, providing a powerful oxidizing agent. It is also a very effective, broad-spectrum oxidizing agent that has found global application in the process industry sector and can be combined with other existing agent in Advanced Oxidation Processes (AOP) for more effective pollution breakdown.

Besides aerobic treatment, pure oxygen is used in many other WWT applications, such as ozone processes and Super Critical Water Oxidation.

Ozone is produced continuously in situ, by passing pure oxygen through an electrical discharge tube. To use ozone for wastewater treatment applications, it must be generated on site and added to the water by direct contact. One of the key advantages of ozone is the fact that it produces very few unwanted and potentially harmful by-products.

Ozone is often used in combination with hydrogen peroxide (H_2O_2) or UV light. This is known commonly as the Advanced Oxidation Process (AOP). AOP is ideal for the removal of recalcitrant dye compounds, pesticide residues and stable organic ring molecules, for example.

Another example of the power of oxygen to treat high-strength waste is Supercritical Water Oxidation (SCWO). This is a process that occurs in water at temperatures and pressures above its thermodynamic critical point, typically greater than 250 bar and >600 degree Celsius. Under these conditions, water becomes a fluid with unique properties that can be used advantageously in the destruction of hazardous wastes such as polychlorinated biphenyls.

SCWO can also be classified as green chemistry or as a clean technology, as recoverable energy is a potential by-product of the oxidation reactions taking place at the supercritical phase. The elevated pressures and temperatures required for SCWO are routinely encountered in industrial applications such as petroleum refining and chemical synthesis.

The solution or solution mix that best fits each customer will depend on a number of factors including the nature of the waste to be treated, throughput requirements and the likelihood of seasonal peaks or changes to the production mix. It is advantageous to team up with a partner like Linde with proven experience in the area of gas-enhanced wastewater treatment to evaluate the various options available and customize both the installation and supporting gas supply scheme to individual needs, while also ensuring adaptability to future changes.

About the author.

Darren Gurney has 25 years of experience in the water treatment field and has developed several of Linde's WT technologies. Originally from United Kingdom, he has a MSc degree in Chemical Engineering and has personally overseen hundreds of installations at wastewater treatment plants across industries as diverse as municipal, food and beverages, textiles, pharmaceuticals, fine and specialty chemicals, and pulp and paper.

"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

Getting ahead through innovation.

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages, and greater profitability.
Each concept is tailored specifically to meet our customers' requirements – offering standardised as well as customised solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow's competition, you need a partner by your side for whom top quality, process optimisation, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde – Ideas become solutions.

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