From Yesterday to Today, Oxygen Continues to Play a Key Role in Water Treatment

A Special Report from Air Products

Oxygen has played a key role in the treatment of drinking water and wastewater for over 40 years. The estimated current global consumption of oxygen in these applications is around 15,000 tons per day. In the US, about 20 percent of municipal drinking water and 50 percent of municipal wastewater is treated with processes that rely on oxygen. The industrial gas industry has been a driving force in the development and introduction of oxygen-based water and wastewater treatment technologies and processes, with Air Products (www.airproducts.com) a recognized leader from the beginning. As environmental and population demands increase, we see continued growth and innovation in this market.

Municipal Wastewater Treatment

Municipal wastewater contains contaminants that impact the environment: solids; materials that remove oxygen from water, referred to as biological oxygen demand or BOD; and nutrients, such as nitrogen and phosphorus, which promote algae growth. Today, most wastewater treatment facilities consist of primary treatment—the removal of solids by settling and skimming—followed by secondary treatment—BOD removal using naturally occurring bacteria. Advanced processes also include treatment for nutrient removal or water reuse.

One of the most significant environmental improvements of the 20th century was the introduction of secondary wastewater treatment and, in particular, the activated sludge process. This process uses large, well-mixed basins to hold wastewater while bacteria, in the form of sludge, consume BOD. The bacteria require significant amounts of oxygen. Water discharged from the basins passes to a clarifier to settle out bacteria sludge prior to discharge.

The activated sludge process was discovered and developed in the United Kingdom around 1910, and by the 1930s was being used successfully for municipal wastewater treatment. Oxygen supply to basins was achieved using atmospheric air aeration.

By the 1960s, existing municipal treatment was not adequate, resulting in large bodies of water suffering low dissolved oxygen, which killed aquatic life. In the US, work started on new approaches to activated sludge, using oxygen rather than air for advanced BOD removal. Air Products and other industrial gas companies developed these processes using covered basins and surface aerators to dissolve oxygen in the wastewater. Air Products’ process, called the OASES® process (OASES® is a registered trademark of I. Kruger, Inc. of Cary, NC) was first introduced in the early 1970s. In the mid-1970s, the US Clean Water Act and the provision of government grant money to support it led to major investments in oxygen wastewater treatment facilities. These wastewater treatment facilities use large amounts of oxygen, and most are supplied with cryogenic air separation units. Smaller facilities use liquid oxygen.

By the mid-1980s, the focus in wastewater treatment expanded from BOD removal to nutrient removal in order to protect sensitive water bodies, such as the Chesapeake Bay, from algae blooms. Air Products was a leader in developing and implementing advanced activated sludge processes called the AO process and the A/O process, which today are widely used in the industry.

By the end of the 1980s, the market for new oxygen activated sludge processes slowed as most municipalities had by now invested in new technology and grant money was no longer available. In 1991, Air Products sold a portion of its wastewater treatment business, which included the OASES® process, but continued to support municipalities with upgrades, turnaround services, and operation and maintenance support to their water treatment facilities, which it still does today. Many of these facilities are now over 20 years old, and the cryogenic plants, in particular, either need major upgrades or replacement. The latest adsorption-based oxygen generation plants are often an attractive solution, providing significant power savings at relatively low cost.

For example, Air Products recently helped the Camden County Municipal Utilities Authority (CCMUA) in New Jersey improve energy efficiency and lower the maintenance of its wastewater treatment plants. Continuing a nearly 20-year relationship with CCMUA, Air Products replaced existing technology with its proprietary PRISM® Oxygen vacuum swing adsorber (VSA) gas generators. The technology will provide CCMUA with a cost-effective solution and an even more reliable gas supply.
**Industrial Wastewater Treatment**

In the 1980s, increasing environmental pressures also impacted industrial wastewater treatment facilities, particularly in Europe. In this market, activated sludge processes were already in place with aeration from air. To minimize capital investment, the focus was on how to get more treatment capacity with existing basins. Industrial gas companies developed a variety of technologies to dissolve oxygen into wastewater. Air Products developed the OXY-DEP™ system, using a recirculation pump with oxygen injection to provide high efficiency dissolution of oxygen. The OXY-DEP system is designed for easy retrofit into basins already using air for aeration. In addition to increasing BOD removal, other benefits include enhanced nutrient removal, reduced sludge production, and lower volatile organic compound emissions.

In the late 1990s, Air Products introduced the OXY-DEP system around the world and now has over 300 industrial installations in markets that include food processing, rendering, chemicals, refining, and municipal.

**Ozone**

Ozone is a very strong oxidizer used in water and wastewater treatment for the removal of bacteria, micro-organisms, and viruses (disinfection), as well as the removal of organics, color, and metals (oxidation).

Ozone was discovered toward the end of the 19th century in Europe. Ozone was made using electrical discharge in air. It was quickly discovered that ozone was a good disinfectant for water, where it found its first successful application. The first municipal drinking water plant to use ozone was located in Nice, France, in 1906.

World War I saw development in the production of toxic gases, like chlorine. After the war, the large scale production of chlorine resulted in the gas becoming readily available for civilian use, and it rapidly took over as the method of choice for most drinking water disinfection.

In the 1970s, problems were identified with the use of chlorine, particularly with the increasing use of surface waters for drinking water supply. Organic materials in the water were found to react with chlorine to produce carcinogenic chlorinated hydrocarbons, such as trihalomethanes. In addition, it was found that certain micro-contaminants and micro-organisms, such as cryptosporidium (a parasite found in contaminated water that affects the intestines of mammals and can cause an acute short-term infection), were not effectively treated with chlorine. Ozone was identified as a leading solution to these problems.

In parallel to this increasing market need, developments in the production of ozone occurred by replacing air with oxygen. This allowed the production of higher ozone concentrations using lower power, with smaller, simpler equipment.

In 1987, Air Products was part of a landmark project in the history of ozone in the US. The City of Los Angeles invested in a new, world-scale drinking water treatment plant (600 million gallons per day—enough water to fill 900 Olympic swimming pools every day) using ozone for disinfection and oxidation. Air Products supplied the cryogenic oxygen plant. Today, about 400 plants in North America use ozone for drinking water treatment.

In the 1980s, oxygen activated sludge processes, such as the OASES process, often used ozone for disinfection prior to discharge. In fact, at this time, wastewater was a larger user of ozone than drinking water. However, the use of ozone in wastewater decreased with time, as lower cost alternatives—like ultraviolet light (UV)—were developed.

Today there is a resurgence of ozone use in municipal wastewater treatment for advanced disinfection for wastewater reuse. This new market need has spurred innovation, and Air Products has introduced the Halia™ Advanced Oxidation Process, which incorporates HiPOx® technology licensed from APTwater, Inc. (HiPOx® is a registered trademark of APTwater, Inc. and is used under license by Air Products and Chemicals, Inc.) The Halia™ Advanced Oxidation Process combines ozone with hydrogen peroxide to produce hydroxyl free radicals—one of the most powerful oxidants available—to treat compounds such as personal care products, herbicides, and other endocrine disrupting compounds increasingly found in drinking water supply. The HiPOx technology is the first ozone-based technology accepted by the State of California for unrestricted water reuse under Title 22 of the California Code of Regulations. (See “Air Products’ Ozone Applications Help Drive Sustainable Water Supply,” CGI, February 2010, pp. 40–41.)

The City of Wichita, Kansas, is constructing a new facility that will use Air Products’ Halia™ Advanced Oxidation Process as a crucial step in treating up to 30 million gallons per day excess water flow from the Little Arkansas River for aquifer storage and future reuse.

**Looking Ahead**

The 21st century will see many new opportunities in water and wastewater treatment, and oxygen will continue to play an important role.

Tighter discharge regulations and the need to reuse wastewater will drive increased use of Membrane Bioreactor (MBR) technology, using high concentration activated sludge followed by membranes that separate sludge from treated water, to produce high quality effluent. The challenges of dissolving oxygen from air at high sludge concentrations can be overcome using oxygen.

Increasing costs associated with industrial waste sludge disposal from activated sludge processes will drive the need to reduce sludge volumes. Oxygen use reduces sludge production, and ozone breaks up sludge so that it can be recycled.

Regulations focused on protecting sensitive waterways will further drive down discharge limits for nutrients. Oxygen processes can offer significant advantages over alternatives that use large amounts of energy and chemicals, and have a larger physical footprint.

While the cost of ozone is high due to power and oxygen consumption, methods to improve efficiency of ozone generation and recover unused oxygen will reduce costs and open up new applications.

With more than 40 years of experience in water and wastewater treatment, Air Products continues to focus on helping municipal and industrial customers operate their plants at peak performance, as well as provide advanced technologies to meet their future treatment needs.

For more information about Air Products’ water and wastewater solutions, marketed under the Halia trade name, call 800-654-4567 (code 845) or visit www.airproducts.com/Halia.