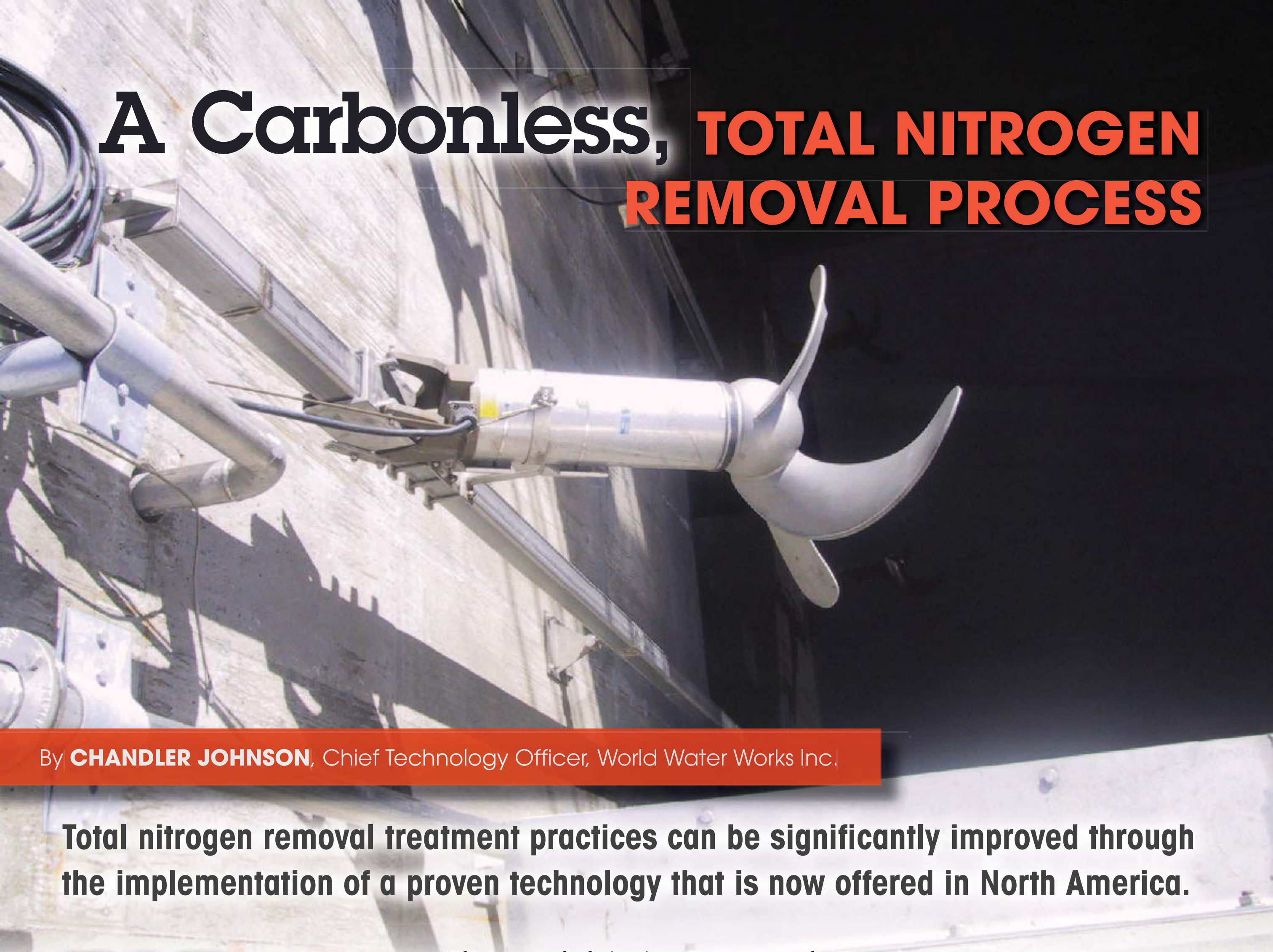


A Carbonless, TOTAL NITROGEN REMOVAL PROCESS

By **CHANDLER JOHNSON**, Chief Technology Officer, World Water Works Inc.

Total nitrogen removal treatment practices can be significantly improved through the implementation of a proven technology that is now offered in North America.

Above is a view of the patent-pending cyclone device that is used for the additional enrichment of the specialized, slowly growing anammox biomass.

Wastewater treatment facilities use a variety of treatment processes to provide safe, effluent levels of water prior to any discharging into waterways. These processes are selected according to several criteria, including the quality of water entering the treatment plant, the quality of refined water that is desired, all capital investments that are required, and any ongoing operational costs that need to be considered, as well as the flexibility and longevity of the treatment processes.

To continuously meet federal and state regulatory agencies' progressively stricter water quality regulations, some wastewater facilities will need to be upgraded in the future. In many areas, such regulations are generally focused on total nitrogen removal, which is an environmentally significant process.

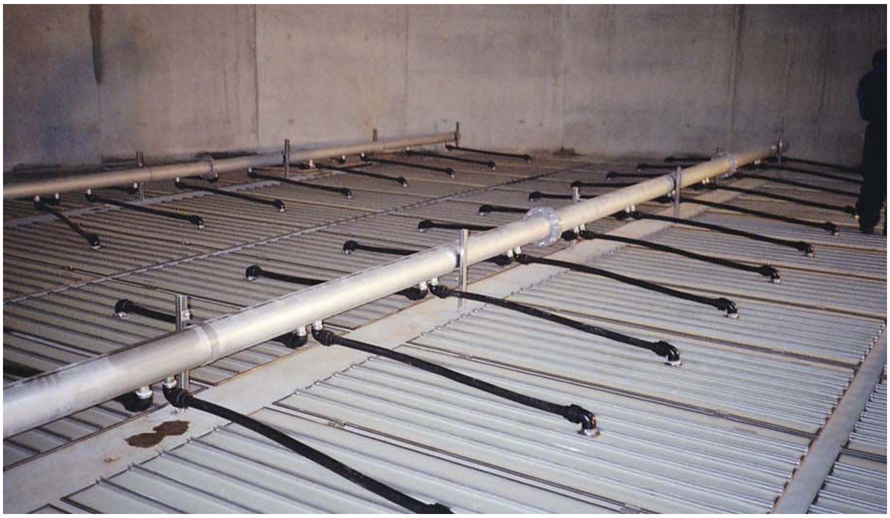
As ammonia is regularly released into the environment, many negative environmental effects are observed, including the oxygen depletion in watercourses and lakes, and the release of nitric oxide or nitrous oxide, which are significant greenhouse gases.

Total nitrogen removal has become one of the more significant cost factors that a wastewater facility faces. To comply with the regulations, facilities are confronted with major plant upgrades that include nitrification and denitrification processes. These systems typically require considerable space and substantial capital upgrades as they regularly increase energy usage and chemical operational costs.

An analysis of the mass balance of a wastewater treatment plant reveals that up to 40 percent of the nitrogen load into the plant occurs while either dewatering the pressate or the centrate stream return line. There is a direct relation between the efficiency of the wastewater solids digestion process and the release of ammonia. This effect is visible in the ammonia concentrations of liquors produced in the dewatering of digested biosolids.

The pressate or centrate from these dewatered solids is then returned to the head of the plant. By treating this side stream, facilities can eventually realize some significant advantages, especially from a financial standpoint.

In Europe, a process known as the DEMON-System has been implemented at more than 20 plants, removing more than 80 percent of the total nitrogen from this side stream. The name of the process is an acronym for DEamMONification. It is a cost-effective technology that completely removes nitrogen compounds from wastewater that has high concentrations of ammonia. The technology is based on a biological process of partial nitritation and autotrophic nitrite reduction. The process was developed and patented by the University of Innsbruck, Austria. It has recently been distributed



Above is a view of the aeration system that is used during the treatment process.

throughout the North American market by World Water Works Inc., which is based in Oklahoma City.

The process tends to have an important role in plant-wide efforts towards energy self-sufficiency by reducing costs and optimizing the footprints of wastewater facilities. The process is characterized by a:

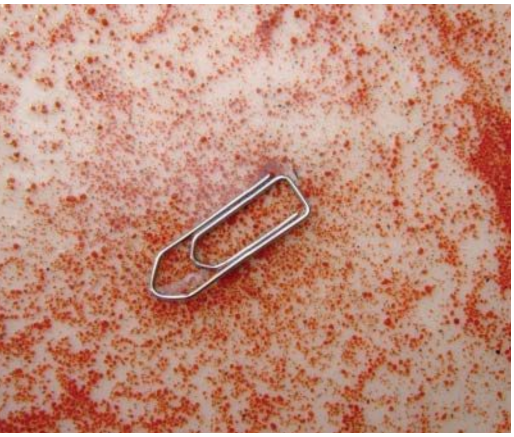
a) 40 percent reduction in energy – only a portion of the ammonia is oxidized to a nitrite compound, resulting in the usage of 40 percent of the oxygen that is required during traditional nitrification processes;

b) Lack of chemical requirements – the denitrification process is completely bypassed, eliminating the need for a carbon source. This savings alone can often yield a less than five-year return on the capital investment;

c) 90 percent reduction in sludge production – since no external carbon source is used for the conversion of nitrite to nitrogen gas, there is a low yield of deammonifying bacteria, resulting in 90 percent less sludge production;

d) CO_2 fixation – the system will fix approximately 0.4 tons of CO_2 per ton of nitrogen removed, in comparison to conventional systems, which will have less than 4.7 tons of CO_2 emissions per ton of nitrogen removed.

During an optimized process scheme of a traditional wastewater treatment plant, most of the biosolids from primary and secondary clarifiers are transferred from



The DEMON process utilizes a consortium of anammox, which is often recognized by an intensely red color, as shown above.

the liquid train to sludge digesters in order to generate methane and provide energy.

The ammonia is released from anaerobic solids digestion; it represents a nitrogen return load of approximately 15 to 40 percent of the overall wastewater load. Processing this high-strength liquor efficiently reduces the side stream nitrogen load by greater than 80 percent. Case studies have demonstrated the feasibility of the energy self-sufficiency of wastewater treatment plants that use this system.

Traditional wastewater nitrogen removal

The removal of nitrogen is affected by the biological oxidation of nitrogen from ammonia to nitrate (nitrification), followed by denitrification, which is the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and, as a result, removed from the water.

Traditional wastewater nitrification/denitrification processes require copious amounts of energy and carbon to obtain low effluent nitrogen limits. Alkalinity is sometimes required to maintain an efficient system while extra sludge is produced due to the use of an external carbon source. Operational dissolved oxygen levels range from 1.0 to 2 mg/L.

Nitrification is the process by which ammonium (NH_4^+) or ammonia (NH_3) is oxidized into nitrite (NO_2^-) by ammonia-oxidizing bacteria (AOB), often Nitrosomonas spp; the NO_2^- is further oxidized into nitrate (NO_3^-) by nitrite-oxidizing bacteria (NOB), often Nitrobacter spp.

Within the two processes of nitrification – nitritation and nitratation – both bacterial groups are chemo-litho-autotrophic, since their only energy source is chemical energy. Their electron-donors are inorganic compounds while their carbon sources are either CO_2, or functionally bicarbonate (HCO_3^-).

By applying the treatment method described here, the maximum possible shortcut of the traditional nitrification / denitrification process can be achieved. The process involves two process steps – the partial nitritation of ammonia and the subsequent anoxic oxidation of the residual ammonia and nitrite to nitrogen gas. About half the amount of ammonia is oxidized to nitrite; afterwards, residual ammonia and nitrite are anoxically transformed to elementary nitrogen gas. The total nitrogen removal is accomplished while using a stoichiometric oxygen demand of only 40 percent. Both process steps are catalyzed by different groups of organisms: a population of aerobic autotrophic ammonia oxidizers, and a consortium of anaerobic autotrophic ammonia oxidizers (anammox) that are characterized by intensely red colors.

Only 40 percent of the energy used by conventional nitrification is required by reducing the amount of ammonia that is converted to nitrite. Additionally, no external carbon source (methanol) is needed due to the autotrophic nature of the process.

Technically, the method is performed in a sequencing batch reactor plant in which the individual steps occur in timely structured occurances. At first, the reactor is gradually filled with centrate and the content is alternately aerated and mixed. Nitritation then occurs during aerated periods while deammonification occurs during anoxic/anaerobic periods. At the end of the fill and aerate phase, both aeration and mixing operations are discontinued while the sludge blanket is allowed to settle. The clear supernatant is then discharged from the reactor.

The sludge then forms large, dense pellets (1,010 cells per ml). The growth rate of this sludge is very low, requiring a mandatory high sludge retention time. Although this sludge has a slow growth rate, it is still quite resilient. Wastewater treatment plants that have just begun to use this process used a concentrated quantity of anammox sludge in order to accelerate the startup process.

Process controls

The system is designed as a fully automated process with a patented control strategy. Finely tuned process controls are necessary in order to closely monitor operating parameters and to maintain consistent, high-quality effluent conditions. Operator participation is limited to assuring that the sensors for pH, oxygen, ammonia and sludge volume measurements are properly calibrated.

> **"Total nitrogen removal has become one of the more significant cost factors that a wastewater facility faces."**

The control system is based on minute variations in pH, resulting in a very simple and stable process operation. The established bandwidth for pH fluctuation is approximately 0.1 pH units. During the fill and aerate phase, the reactor is alternately aerated to convert ammonia into nitrite, which leads to a decrease in pH levels. When aeration is halted, the pH will rise. The aeration is then restarted and the cycle is repeated.

The relative change in pH value is especially critical. Nitrite oxidizing bacteria compete with anammox for the available nitrite, producing changes in pH that are used to monitor nitrite production. The measurement of relative pH changes over a short time period is generally accurate enough to control the process.

Enriching the anammox biomass

A significant feature of this process is its patent-pending cyclone device for additional enrichment of the specialized anammox biomass. Since anammox is predominantly aggregated in a heavy granular fraction, the cyclone-produced centrifugal forces select the anammox populations, while wasting the AOB/NOB populations, and decouple the sludge retention time (SRT) from the system's operation. The substantially higher mass of anammox within the system compensates for the slower kinetics of these organisms in comparison to AOBs. A surplus in the retention of compact red granules enhances process robustness and treatment capacity.

By doubling the mass ratio of anammox compared to aerobic AOB, the robustness of the process, against disturbances such as over aeration, temperature drop or a flush of excess organic carbon, is drastically improved.

Ammonia removal efficiency

The process can be successfully applied to the removal of ammonia from sludge liquors, without the need for an external carbon source or any other chemical.

Using a cyclone in the process allows different types of SRT durations as needed by different types of bacteria, thus greatly enhancing process stability.

Centrates can demonstrate large variations in ammonia concentration, which are mainly caused by the digestion of different batches of biosolids. Despite these variations, the process consistently operates with an ammonia removal efficiency of 85 to 92 percent. This ammonia load reduction is a critical benefit to the main treatment process.

Since the system saves 60 percent of a conventional plant's energy consumption, and the dosage of external carbon can be completely avoided, the amount of excess sludge produced is also significantly reduced, minimizing disposal costs.

In addition to significant energy savings, as well as the complete abandonment of organic carbon, the process reduces greenhouse gas production. While other biological processes produce large quantities of CO_2 the system described here does not.

For industrial wastewater plant applications, the benefits of applying this process are significant. Initially, the carbon (BOD) is eliminated, and in a further stage, the nitrogen is removed.. ***PE***

For more information, please contact Neil McAdam, vice president of sales for World Water Works Inc. either by phone at (405) 943-9000 or by email at mcadam@worldwaterworks.com. Also, please visit www.worldwaterworks.com.

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