SEDAC
SMART ENERGY DESIGN ASSISTANCE CENTER

Public Water Infrastructure Program

Efficient Nitrogen and Phosphorous Removal

Introduction to Wastewater Treatment

Wastewater treatment facilities are commonly required to implement treatment processes that reduce effluent nutrient concentrations to levels that regulators deem sufficiently protective of receiving waters and preventative against eutrophication, particularly in rivers and streams.

Almost all wastewater treatment plants (WWTPs) perform at least a secondary treatment of their wastewater. However, given the complex requirements associated with this treatment process, most WWTPs do not provide enough nutrient removal. Thus, in 2019, the National Pollutant Discharge Elimination System (NPDES) permit imposed limits meant to achieve a 20-50% reduction in nitrogen and phosphorus.

Nutrient removal processes include physical treatment (sedimentation and filtration) for particulates, and chemical and biological treatment for dissolved nutrients.

Efficiency Factors

Most activated sludge plants achieve enhanced biological nitrogen removal through a two-step process of nitrification and denitrification. Nitrification converts ammonia to nitrite, then nitrate in aerobic zones. Anoxic conditions allow for dentirification, which also releases alkalinity into the water.

Phosphorus removal requires an anaerobic environment and consumes alkalinity and carbon. Many nutrient removal designs have the phosphorus removal basin first, followed by an anoxic basin and aerated basin. The anaerobic requirement of the initial basin is more easily met with influent flows that are already lower in DO content prior to aeration, and the alkalinity trade-off between phosphorus removal and denitrification helps balance water chemistry for the aerobic nitrification process.

EBNR Technology Overview

In general, BNR requires a lot of recycle pumping energy to effectively remove nutrients, and there is significant risk of upsetting the process if DO levels and recycle rates aren't closely controlled.

Energy efficiency can be obtained by reducing the need to recycle plant flows, and optimizing aeration and mixing.

Major components of diffused aeration systems are the air intake system, blowers, the air piping system, diffusers, and controls.

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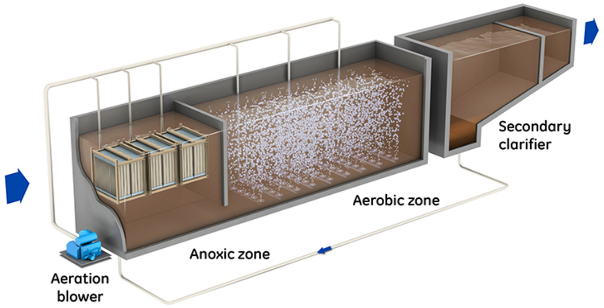
EBNR Technology Overview (cont.)

Simultaneous nitrification/denitrification (SNDN) is a biological method for the removal of nitrogenous compounds from wastewater. This method combines the activities of nitrifying and denitrifying bacteria in one compartment to achieve near complete removal of nitrogen. Such a setup allows WWTPs to be more efficient while producing a high-quality effluent. Common technologies used to achieve simultaneous nitrification and denitrification include:

1. Membrane Aerated Biofilm Reactor (MABR)
MABR is a fixed film process and provides simultaneous nitrification-denitrification in anoxic conditions where it can be integrated as an alternative for bubble aeration. The membrane is used to passively deliver oxygen in the molecular form. This SNDN process eliminates the need for recirculation pumping between basins and increases aeration efficiency by eliminating the loss of air to bubbles rising to the surface of the reactor basin. In general, MABR can be four times more efficient than conventional fine bubble diffusers[1].

2. Moving- Bed Biofilm Reactor (MBBR)
An MBBR system is an aerobic, single pass, and attached growth process with no activated sludge recycle. Biofilm carriers are mixed with the wastewater stream and suspended. As a result, the bacteria that accumulate on the biofilm carriers break down the organics in the wastewater and convert them into biomass, thus nitrifying, denitrifying, and removing BOD. After the bioreactor, sludge settlement is required in the form of lamella technology to remove particulates from the water. This treatment method provides a few different advantages for wastewater treatment plants. Primarily, it increases treatment capacity without additional plant expansion and offers lower operational cost than other SNDN processes.

1 (Peeters and Natvik, 2021)



EBNR Technology Overview (cont.)

3. Integrated Fixed Film Activated Sludge (IFAS)
Unlike the MBBR, this system includes activated sludge recycling, allowing it to be retrofitted onto an existing activated sludge system. This process:

- Provides simultaneous phosphorus removal and SNDN due to thickness of biofilm layer creating aerobic, anoxic, and anaerobic layers.
- Increases sludge retention time, increasing treatment capacity in the same basin volume.
- System nitrification recovers more quickly after upsets due to larger mass of nitrifiers.
- Sludge production is reduced over other system types.

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Side-Stream Enhanced Biological Phosphorus Removal (S2EBPR)

Side-stream enhanced biological phosphorus removal processes (S2EBPR) refer to a modified EBPR configuration or Anaerobic-Anoxic-Aerobic (A2O) design that improves performance stability and offers a suite of advantages compared to conventional EBPR. This configuration diverts a portion of the return activated sludge to a side-stream anaerobic reactor where volatile fatty acids (VFA) are generated via sludge hydrolysis and fermentation. In addition, this process can reduce or eliminate the need for external carbon addition and minimize chemical usage by taking advantage of the generated VFAs, which in turn enhance denitrification and reduce treatment process dependence on the carbon/phosphorous ratio from influent. Additional advantages of this configuration include:

- Uses similar or less tank volume than standard EBPR.
- Can be readily incorporated into existing tanks.
- Allows more influent carbon for denitrification.

Sidestream Deammonification

The deammonification process replaces conventional nitrification/denitrification (N/DN) with a partial nitrification and annamox bacterial reaction (PN/A). This alternative sidestream process requires conversion of approximately half of the influent ammonia into nitrite by ammonia oxidizing bacteria (AOB), followed by the simultaneous removal of ammonia and nitrite by anammox bacteria. Under anoxic conditions, anammox can simultaneously reduce nitrite and ammonia to nitrogen gas. This process allows for:

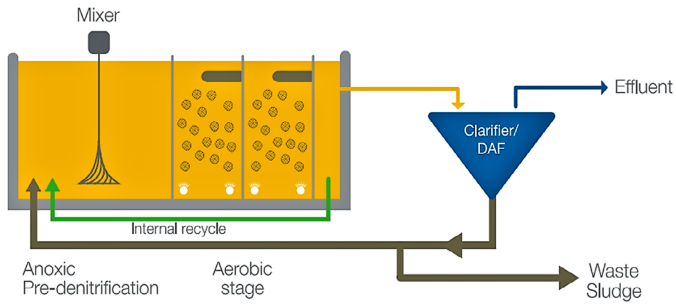
- Approximately 60% reduction in oxygen demand, which can be translated to a reduction in energy from blowers.
- Elimination of the need for supplemental carbon to meet low total nitrogen during heterotrophic denitrification.
- 80% reduction in sludge processing (eg., sidestream digestion, drying, hauling costs).

Hyperbolic Mixer

A new hyperbolic mixer has undergone full-scale testing at two large wastewater treatment plants in the U.S. and has shown significant energy savings compared to traditional submersible mixers. The hyperbolic mixer has been used in Europe for more than ten years with installations in Germany, Holland, and Belgium[1]. Researchers evaluated the two mixers based on their ability to:

- Sustain uniform distribution of suspended solids in the basin.
- Maintain a low DO concentration (< 0.3 milligrams per liter).

1 (Gidugu et al. 2010)



Have a Question About the Public Water Infrastructure Program? Contact Us.

WHO WE ARE

SEDAC provides energy assessments, education and technical assistance. This program is in partnership with the U.S. Dept. of Energy Sustainable Wastewater Infrastructure of the Future (SWIFT) accelerator for energy efficiency in wastewater treatment, and a partner for the Public Water Infrastructure Energy Efficiency Program with the Illinois EPA Office of Energy

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