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Editorial

Special Issue on "Anammox-Based Processes for Wastewater Treatment"

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Anaerobic ammonium oxidation (anammox, A) has become an appealing bioprocess for the water sector as a method to remove nitrogen (N) from wastewater using low-energy and organic carbon inputs. Its development has come a long way since its discovery at the beginning of the 1990s [1,2]. Anammox involves the simultaneous conversion of ammonium (NH_4^+) and nitrite (NO_2^-) to nitrogen gas (N_2) and nitrate (NO_3^-) under anaerobic conditions. To produce nitrite, the anammox process is commonly coupled with partial nitritation (PN), which can be engineered in a single tank or in two different tanks. Overall, the PN/A process consumes 60% less oxygen, produces about 90% less sludge, and consumes 100% less organic carbon compared with conventional nitrification/denitrification (N/DN) [3].

Nowadays, the PN/A process offers mature alternatives for the treatment of dewatering liquors (sidestream) resulting from anaerobic digestion (i.e., mesophilic sludge digestion, codigestion, anaerobic digestion after a thermal hydrolysis process) in urban wastewater treatment plants (WWTPs), as well as of some other high-strength industrial wastewaters. Treatment of the mainstream in WWTPs, as well as of other complex wastewaters, is moving forward, although it still requires further development to be implemented safely [3,4]. This Special Issue on "Anammox-Based Processes for Wastewater Treatment" collates nine articles that describe advances in the development and application of anammox in wastewater treatment. The Special Issue is available online at: https://www.mdpi.com/journal/processes/special_issues/anammox_processes_wastewater_treatment (accessed on 18 April 2023).

Urban wastewaters

The PN/A process can improve the energy efficiency in WWTPs as well as diminish operational costs. Pedrouso et al. [5] performed a theoretical study and confirmed the interest in thermally pretreating the sludge in the sidestream to increase biogas production before a PN/A single-tank unit. Moreover, this paper also assessed the effect of promoting the growth of ammonia-oxidizing bacteria (AOB) in the sidestream to carry out their bioaugmentation in the mainstream in view of the PN/A process. The achievement of a suitable effluent quality was promoted by heterotrophic denitrification, adjusting excess nitrate—generated by anammox bacteria (AnAOB) and/or nitrite-oxidizing bacteria (NOB)—to meet the discharge requirements.

Concerning particular technologies for the sidestream, Driessen and Hendrickx [6] reviewed full-scale experiences with the granular sludge-based ANAMMOX® process. Long-term operations of various case studies showed a stable process performance, reaching removal efficiencies of 90% at low and high loading rates of up to 2.5 kg NH_4^+–N/(m^3·d). Similarly, Lemaire and Christensson [7] reviewed experiences with the ANITA™ Mox process based on the moving bed biofilm reactor technology. AnAOB and AOB are retained in a biofilm on moving carriers with no risk of biomass wash-out. By taking into account the existing facilities for both of the technologies referred to above, the number of full-scale installations existing worldwide reaches about 100 units. Alternatively, Ochs et al. [8] evaluated the performance and stability of a full-scale suspended sludge continuously stirred tank reactor with a hydrocyclone for anammox biomass separation. The hydrocyclone was responsible for retaining about 60–80% of the AnAOB, and the washout of AOB and NOB was two times greater than that of AnAOB.

Finally, Huang et al. [9] coupled partial denitrification (PD) with anammox (PD/A) on a lab scale in a continuous-flow anoxic/oxic biofilm reactor to treat urban wastewater. Ammonium oxidation to nitrate occurred in the oxic zone, whereas nitrite accumulation occurred in the anoxic zone due to the insufficient availability of organic carbon to complete nitrate reduction to nitrogen gas. After the inoculation of anammox sludge to anoxic zones, AnAOB were effectively retained in the anoxic biofilm using the nitrite produced via PD and the ammonium present in the wastewater.

Urban landfill leachate

The biological treatment of landfill leachates using anammox is challenging because of the characteristics of this complex wastewater. Magrí et al. [10] described the scaling-up and long-term operation of a full-scale two-step PN/A unit, in which conductivity above a certain threshold could negatively affect the performance of the process. A pre-treatment step targeting adjusting alkalinity before biological treatment was essential to produce a good-quality nitritated effluent to feed the anammox process downstream. The heterotrophic activity in the PN reactor also favored softening the impact on the anammox process caused by the availability of biodegradable organic carbon in the leachate. On the other hand, Lanzeta et al. [11] modeled two full-scale one-step reactors operated to achieve two different N removal bioprocesses (i.e., PN/A and simultaneous partial nitrification/denitrification (SPND)). Despite the different strategies applied in terms of aeration and mixing patterns, the results aided in understanding that the PN/A process was the main contributor to N removal when the availability of organic carbon was low. By increasing the external carbon addition, a fast decrease in the anammox activity was observed, with SPND becoming the main N removal mechanism.

Livestock and aquaculture effluents

Waki et al. [12] reported the spontaneous enrichment of anammox biofilms in swine wastewater N/DN treatment facilities running under low dissolved oxygen levels. Such installations could easily be converted to anammox-based treatment units or used as seed sources for the inoculation of new anammox reactors. The aquaculture sector is growing fast as an essential source of food, and recirculating aquaculture systems (RAS) are promising candidates for sustainable development. Roque et al. [13] investigated the potential of the anammox process to treat marine wastewater from cold-water RAS, obtaining promising results. The activity of AnAOB was negatively impacted after direct exposure to wastewater from the RAS, making necessary the establishment of an appropriate acclimatization procedure.

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Acronyms

anammox (A)	Anaerobic ammonium oxidation
AnAOB	Anaerobic ammonium-oxidizing bacteria
AOB	Ammonia-oxidizing bacteria
N	Nitrogen
N/DN	Nitrification/denitrification
NOB	Nitrite-oxidizing bacteria

PD	Partial denitrification
PD/A	PD/anammox
PN	partial nitritation
PN/A	PN/anammox
RAS	Recirculating aquaculture systems
SPND	Simultaneous partial nitrification/denitrification
WWTP	Wastewater treatment plant

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