28.4 SNAD process

What is SNAD process? SNAD stands for Simultaneous partial Nitrification, ANAMMOX (anaerobic ammonium oxidation), and Denitrification. The SNAD process includes three chemical reactions in a single reactor. In other words, it is an integration of three reactions namely partial nitrification (Eq. 6.179a), ANAMMOX (Eq. 6.183a) and denitrification (Eq. 6.200a) in a single reactor. It is the most efficient and economical biological process to treat wastewaters containing low organic carbon to nitrogen ratio (C/N).

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + H_2O + 2H^+ \qquad (6.179a)$$

$$1NH_3 + 1.3NO_2^- + H^+ \rightarrow 1.02N_2 + 0.26NO_3^- + 2H_2O \qquad (6.183a)$$

$$6NO_3^- + 5CH_3OH + CO_2 \rightarrow 3N_2 + 6HCO_3 + 7H_2O \qquad (6.200a)$$

Background and theories. Anaerobic ammonia oxidation (ANAMMOX) is the latest update treatment process for nitrogen removal in the global. In this process, ammonia is oxidized under anaerobic conditions by using nitrite as an electron acceptor (Eq. 6.183a). This process is carried out by specific bacteria commonly named anaerobic ammonia oxidizing bacteria or anammox bacteria. Since ANAMMOX process is anaerobic and doesn't require organic carbon to convert ammonia nitrogen to nitrogen gas, it has gained lots of attention in recent years. Many scientists and engineers from all over the world have been interested in applying anammox technology to treat nitrogen rich wastewaters. As the electron acceptor nitrite is not present in wastewaters, the ANAMMOX reaction (Eq. 6.183a) is usually combined with partial nitrification (Eq. 6.179a) either in a two-reactor system called SHARON (an acronym for Single reactor High activity Ammonia Removal Over Nitrite)-Anammox or in a single reactor system called CANON. However, the SHARON-Anammox or CANON process has two limitations. It does not remove organic carbon that is generally present in wastewater systems along with ammonium nitrogen and it generates nitrate as a byproduct, which further treatment may be needs in some cases.

In order to overcome these two problems, the SNAD process has been developed by Chen et al. (2009). In this process, three bacterial communities i.e. aerobic ammonia oxidizing bacteria (AOB), ANAMMOX bacteria, and denitrifying bacteria co-exist in a single reactor under oxygen limiting conditions. And they are responsible for simultaneous removal of inorganic nitrogen and organic carbon. The co-existence of AOB, anammox bacteria and heterotrophic denitrifying bacteria in the sludge of SNAD reactor has been confirmed by scanning electron microscopic observation, polymerase chain reaction (PCR) analysis and fluorescence in situ hybridizations (FISH) analysis (Chen et al. 2009; Wang et al. 2010).

In the SNAD process, first ammonia is converted partially to nitrite (Eq. 6.179a) by AOB, which consume oxygen and create anoxic conditions. Subsequently, ANAMMOX bacteria convert ammonia and nitrite to nitrogen gas and nitrate (Eq. 6.183a) under anoxic conditions. Finally, denitrifying bacteria reduce nitrate produced by ANAMMOX bacteria to nitrogen gas by consuming organic carbon (COD) as reducing agent (Eq. 6.200a).

However, the challenging issue for integrating ANAMMOX and denitrification in a single reactor is the competition between an ANAMMOX and denitrifying bacteria for nitrite (Kumar and Lin 2010). Therefore, ANAMMOX bacteria should dominate over denitrifying bacteria for a successful and stable operation of SNAD system. The SNAD patented process is based on seeding and also the one bio-reactor design. The major bacteria are *Nitrosomonas* (commonly called ammonia oxidizing bacteria, AOB) for partially ammonia oxidation; ANAMMOX (anaerobic ammonia oxidizing bacteria for the ANAMMOX processs; and *Nitrobacter* (commonly called nitrite oxidizing bacteria, NOB) for denitrification. The presence of ammonium oxidizing bacteria and ANAMMOX bacteria were confirmed by polymerase chain reaction (PCR). PCR results also indicated that ANAMMOX bacteria is named candidatus *Kuenenia stuttgartiensis* may be one of the dominant species in the reactor (, 2009).

Benefits. In comparison to the conventional nitrification/denitrification process for nitrogen control in a wastewater treatment, this newly developed and patented SNAD process reduces oxygen supply by 60% and power costs, footprint, chemical (reducing agent) use, and sludge production, and is no need for carbon addition. Thus there is a substantial cost reduction for capital investment and for O/M. In addition, during the process of biochemical reaction micro-organisms utilize HCO_3^- in wastewater as a carbon a source; this reduces the emission of CO_2 in air and a benefit of the reduction of green- house effects. Therefore, the SNAD process would be an important technology for wastewater treatment. Comparisons of nitrification/denitrification process and SNAD process are shown as below:

Item	Conventional nitrification/denitrification	SNAD
Reactor	2 (aerobic and anaerobic)	one
Oxygen demand, g O_2/g of NH_4^+- N	4.3	1.8
Organic carbon demand, g COD/g of NH_4^+- N	4.1	None
Sludge production, g biomass/g of NH_4^+- N	1.5	0.2
Cost, $/kg of N removed	2,75	0.80

Source: Chen, et al. 2009

Examples of field applications (a proven technology). The SNAD process has been successfully developed as a proven technology for simultaneous removal of nitrogen (ammonia) and organic matter (COD) from different wastewaters such as leachate wastewater (Wang et al. 2010), optoelectronic industrial wastewater (Daverey et al. 2012), fertilizer industry effluent, (Keluskar et al. 2013) and anaerobic digester liquor of swine wastewater (Daverey et al. 2013).

The first full-scale application of SNAD process in Taiwan was reported in a landfill-leachate treatment plant at Tianwaitian operated by Leaderman & Associates Co., Ltd. and confirmed by research group at National Chiao Tung University (NCTU), Taiwan. The nitrogen removal via combined partial nitrification and ANAMMOX reaction was 68%, while denitrification removed 8% of total nitrogen. Also, 23% of COD was removed via denitrification in this process (Wang et al. 2010). Furthermore, the SNAD process has been proven to be replicated in a lab-scale.

Upon the successful lab-scale cultivation of SNAD seed sludge, NCTU research group and Leaderman & Associates Co., Ltd have successfully transferred the SNAD process to two other leachate treatment plants (Keelung and Bali) in Taiwan. The Keelung Landfill Leachate

Treatment Plant has flow rate of 350 m^3/d and a nitrogen loading of 180 kg-N/d. The Bali Plant treats 800 m^3/d flow rate with 480 kg-N/d. The sludge from Tianwaitian full-scale landfill-leachate treatment plant has been successfully tested for the treatment of optoelectronic industrial wastewater and anaerobic digester liquor of swine wastewater (Daverey et al. 2012; Daverey et al. 2013).

Summary. SNAD - an ANAMMOX based process has potential to successfully remove the nitrogen and carbon compounds from wastewater in lab- and field-scale tests. The new process achieves many advantages over the conventional and improved processes. Its applications can be applied to treat other industrial wastewaters in the future. The SNAD process can be employed by the treatments of high content of wastewater including land-fill leachate, feed lots, aquaculture, domestic sewage, and varieties of industrial wastewaters, such as chemical, fertilizer, armory manufactures, metal-cutting, chemical processing, etc.

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Will be acknowledged in the Preface of my book

Dr. Achlesh Daverey and Prof. Jih-Gaw Lin both of National Chiao Tung University, Hsinchu, Taiwan, and Mr. Der-ming Lee of Leaderman & Associates Co, Taipei, Taiwan prepared the

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黎明興技術顧問股份有限公司所研發新穎生物除氮技術-SNAD，將摘錄於林順達博士最新撰寫之给水与排水计算手册"Water and Wastewater Calculations Manual"第三版。預計於 2014 年 4 月由 McGraw-Hill Book Co 發行。