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Nitrogen removal from old landfill leachate with SNAP technology using biofix as a biomass carrier

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Single-stage nitrogen removal using Anammox and partial nitritation (SNAP) is a novel technology developed in recent years for removing nitrogen. To evaluate the ability of SNAP technology to remove nitrogen in old landfill leachate under the conditions in Vietnam, we conducted a survey with 7 different nitrogen loading rates of 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 kg-N/m^3 day and a concentration from 100 to 700 mg-N/L. The operating conditions were as follows: DO at 1.0–5.3 mg/L, HRT at 12 h, and pH at 7.5–7.8. The biomass carrier was a biofix made from acrylic fiber. The maximum ammonium conversion and nitrogen removal efficiency were approximately 98% and 85%, respectively, at 1.2 kg-N/m^3 day. In general, the nitrogen removal efficiency increased and stabilized at the end of each loading rate. The first step showed that SNAP could potentially be applied in real life for removing nitrogen from old landfill leachate.

[**Key words:** SNAP; Anammox; Nitritation; Old landfill leachate; Biofix]

Leachate is generated from landfills of municipal solid waste and is a major concern for the surrounding environment. Its negative impacts include damaging the receiving sources if it has not been thoroughly treated. In particular, the nitrogen concentration in leachate is relatively high. Therefore, the problem of treating nitrogen in the leachate is a subject concerning scientists in particular and each nation in general. Conventional nitrification/denitrification technologies are not suited for treating old landfill leachate with high ammonium nitrogen concentrations and low biodegradable organic matter content (1). Traditional technologies require additional external carbon sources and large energy consumption and so on.

Thus, applied research has been conducted on individual or combined partial nitritation and anammox processes to reduce operating costs and ensure the nitrogen processing efficiency with a high nitrogen loading rate, such as single reactor system for high ammonium removal over nitrite (SHARON-Anammox) (2), completely autotrophic nitrogen removal over nitrite (CANON) (3), oxygen-limited autotrophic nitrification-denitrification (OLAND) (4), and single-stage nitrogen removal using Anammox and partial nitritation (SNAP) (5). Compared with conventional nitrification/denitrification technologies, partial nitritation/anammox reduced 85% of the oxygen requirement, 100% of the carbon requirement and 83% of the bio-solid production (6).

The SNAP process is based on two biotechnologies. In the first, partial nitritation, ammonium is partly nitrified to nitrite by ammonia-oxidizing bacteria (AOB) (Eq. 1) (5), and then the resulting nitrite is denitrified with the residual ammonium in the Anammox (Eq. 2) (7).

$$2NH_4^+ + 1.5O_2 \rightarrow 1NH_4^+ + 1NO_2^- + 1H_2O + 2H^+ \quad (1)$$

$$1NH_4^+ + 1.146NO_2^- \rightarrow 0.986N_2 + 0.161NO_3^- + 2H_2O \quad (2)$$

The overall reaction is described in Eqs. 3 and 5:

$$1NH_4^+ + 0.85O_2 \rightarrow 0.44N_2 + 0.11NO_3^- + 1.43H_2O + 1.14H^+ \quad (3)$$

In a few recent studies on SNAP, Lieu et al. (8) performed more research on SNAP technology with a landfill leachate with low ammonium nitrogen. Takekawa et al. (9) studied the effects of the operational conditions of the SNAP process. Hien et al. (10) evaluated the nitrogen removal efficiency from synthesized wastewater with a high nitrogen concentration using SNAP technology. Further research is required on SNAP technology for the treatment of real landfill leachate with high ammonium nitrogen concentrations to create a precondition for the application of this technology in practice under conditions in Vietnam.

MATERIALS AND METHODS

Experimental set-up and operational conditions The SNAP reactor design features a cylinder with a conical bottom made of acrylic resin and a working volume of 6.5 L. Its internal diameter and useful height tank are 150 mm and 420 mm, respectively. The schematic diagram of the experiment is shown in Fig. 1. The biomass carrier used in this research is biofix, which is made from a hydrophilic net-type acryl resin fiber material (NET Co., Ltd., Hyogo, Japan). The characteristics of this biomass carrier are shown in Table 1 and Fig. 2. The biofix used had a weight of 41.2 g and was fixed by cylindrical frames with an external diameter of 92 mm, inner diameter of 62 mm and height of 300 mm.

The reactor operated with uncontrolled temperature and depended entirely on the ambient temperature, which ranged from 27°C to 35°C. Air was fed into the

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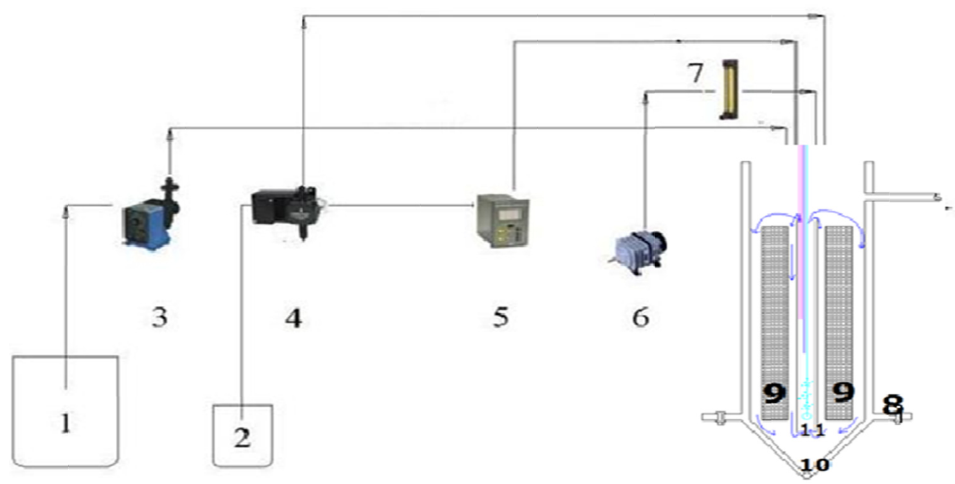

1. Influent tank
2. $NaHCO_3$ solution
3. Influent pump
4. $NaHCO_3$ pump
5. pH controller
6. Air pump
7. Air-controlling valve
8. Reactor
9. Biomass carriers
10. Discharge valve sludge
11. Center resin tube

FIG. 1. Schematic diagram of experimental apparatus.

reactor through the bottom of the center tube and controlled by an air-controlling valve such that the dissolved oxygen (DO) did not exceed 1 mg/L. The DO increased gradually with increasing nitrogen loading rate. The pH and hydraulic retention time (HRT) were suitable for SNAP, pH 7.5–7.8 and 12 h, respectively (5). $NaHCO_3$ solution (0.5 N) was used to control the pH value through a pH controller.

In addition, to achieve partial nitritation and avoid the production of nitrate ($NO_3^- - N$), the operation required certain conditions, such as a low dissolved oxygen concentration (DO) (11–13), high temperature (14), pH (15) and free ammonia concentration (FA) (16). The DO was strictly controlled, as mentioned above, with a measurement frequency of 2 times/day. FA was controlled through the adjustment of the ammonium concentration and pH in the tank. During the Tet holiday, the research was maintained with the operating condition of an NLR of 0.6 kg-N/m^3 day.

Seed sludge and influent wastewater The anammox sludge and the activated sludge seeding in the reactor were 6 g/L and 4 g/L, respectively (5). They were mixed into the SNAP sludge. The total seed sludge was 5 g/L (MLSS). The anammox sludge and activated sludge were obtained from Kumamoto University, Japan, and the Tan Binh wastewater treatment plant, Vietnam, respectively.

In this study, a synthetic landfill leachate simulating pretreated leachate was used as the influent for the start-up phase for the SNAP sludge. Then, the synthetic leachate and old leachate were mixed together at different ratios (the ratios of synthetic leachate and old leachate were two weeks each of 8:2, 6:4, 4:6, and 2:8) until the old landfill leachate was completely replaced at 0.4 kg-N/m^3 day. When real landfill leachate was used in the experiment, the nitrogen concentration in the influent wastewater increased to achieve nitritation and the SNAP process. The composition of the synthetic and old landfill leachate are shown in Tables 2 and 3, respectively.

Chemical analysis Standard Methods for the Examination of Water and Wastewater (USA) were used to analyze ammonium-nitrogen ($NH_4^+ - N$), nitrite-nitrogen ($NO_2^- - N$) and nitrate-nitrogen ($NO_3^- - N$), including $NH_4^+ - N$: 4500-NH_3-B Preliminary Distillation Step, $NO_2^- - N : 4500{-}NO_2^- - B$ Colorimetric Method, and $NO_3^- - N : 4500{-}NO_3^- - E$ Cadmium Reduction Method (17). The total nitrogen was defined by TCVN 6638:2000 (National Technical Regulation Vietnam), Catalytic digestion-devarda alloy (18). The pH was controlled by pH controller BL 931700, Hanna–England. DO was measured using EXTECH 407510–Taiwan.

Polymerase chain reaction–PCR Polymerase chain reaction (PCR) analysis was conducted to confirm the existence and identification of nitrifying and anammox bacteria in the SNAP sludge. The entire analytical process was conducted by the

TABLE 1. Properties of acryl-fiber biomass carrier.

Parameter	Value[a]
Specific yarn length (m/m^3)	23.324
Specific surface area (m^2/m^3)	146.5
Yarn diameter (mm)	2

[a] Provided by the manufacturer.

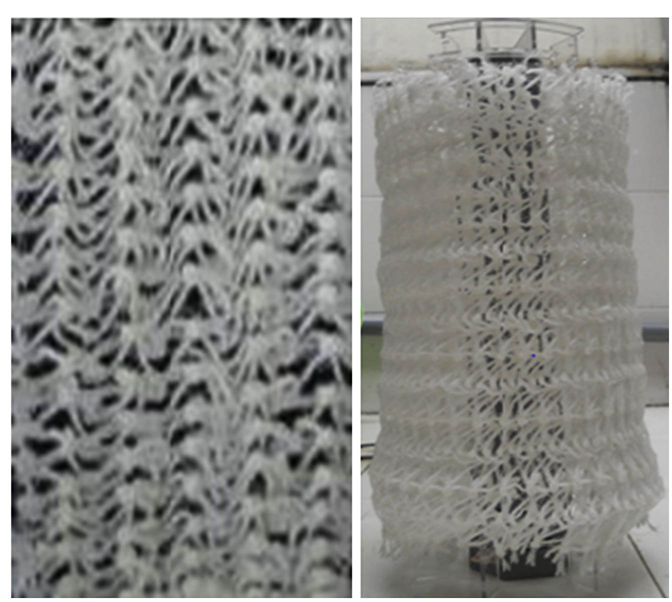

FIG. 2. Photos of biomass carriers and biomass carrier fixed on steel frames.