19th International Conference on Environmental Science and Technology

Kos, Greece, 3 to 6 September 2025

Performance of sequencing batch reactors for the treatment of high ammonium concentration landfill leachate

Lu, P.[1], Glasgow, G.[2*], Lay, M.[2]

[1]GWE Consulting Ltd, 25 Anzac Street, Takapuna, Auckland, 0622, New Zealand
[2]School of Engineering, Faculty of Science and Engineering, University of Waikato, Hamilton, 3240, New Zealand

*corresponding author
e-mail:graeme.glasgow@waikato.ac.nz

Abstract The contaminated liquid produced from rainfall seeping through the layers of waste in domestic landfill sites is known as leachate. Leachate from landfills is high in nitrogen content, mostly as ammonium, and is typically disposed of by transportation to a domestic wastewater treatment plant at a cost. Sequencing batch reactors (SBR) are compact fill-and-draw activated sludge systems that facilitate treatment in a singular reactor, including ammonium removal through nitrification. This study examines the viability of on-site SBRs nitrifying the high ammonium concentrations found in landfill leachate in New Zealand instead of transportation off-site. Two 1 litre volume SBRs were operated for over 6 months with increasing concentrations of ammonium in the feed to determine ammonium removal. The reactors achieved significant ammonium removal at influent ammonium loading as high as 720 mg/L. pH control was required at higher influent ammonium loadings above 300 mg/L to prevent inhibition of the nitrifying bacteria by acidification. These results suggest that onsite SBR system can be made a viable option for leachate treatment in New Zealand.

Keywords: landfill leachate, sequencing batch reactor, ammonia, nitrification

1. Introduction

Solid waste management is advancing globally to reduce landfill use through treatment and resource recovery. In 2009, New Zealand landfilled 3.156 million tonnes of waste, which mainly consists of materials with limited recycling potential [Ministry of the Environment, 2009]. Landfills operate under strict regulations to minimize environmental harm, particularly to air, soil, and water. Precipitation generates leachate, a contaminated liquid that percolates through waste, posing risks to surface and groundwater [Foo and Hameed, 2009]. Ammoniacal nitrogen (NH_4-N) is a major pollutant in leachate, causing eutrophication and chemical imbalances in aquatic systems. Leachate is more challenging to treat than domestic wastewater due to its complex composition. While co-treatment with domestic wastewater is possible, transportation costs can be prohibitive [Brennan, R.B., et al., 2017]. Sequencing Batch Reactors (SBRs) offer potentially efficient on-site treatment suited to leachate's low and variable flow, especially in remote areas like New Zealand's Waikato region [Danley-Thomson, A., et al., 2020]. This study investigates seeding SBRs with cow manure, a readily available material, to treat high-ammonia leachate. SBRs treat wastewater in a single tank through fill, react, settle, decant, and idle phases. During the react phase, aeration supports nitrifying bacteria converting ammonia to nitrites and nitrates, consuming oxygen and alkalinity. A dissolved oxygen (DO) level of at least 2 mg/L is typically required, though lower DO or intermittent aeration can enable simultaneous nitrification and denitrification [Iannacone, F., et al., 2019]. SBRs can achieve ammonia removal efficiencies up to 98%, but establishing effective sludge can take 29 to 120 days [Rizvi, H., et al., 2015].

2. Method

One litre lab-scale sequencing batch reactors (SBRs), shown in Figure 1, were operated using a Winpact Parallel System Controller with integrated pH, dissolved oxygen (DO), and temperature probes. Ammonium concentration in the SBRs was measured using a calibrated Vernier ion-selective electrode, collecting 24-hour cycle data for analysis. Each SBR included aeration, stirring and peristaltic pumps for influent and effluent handling. A 24-hour cycle was adopted, with a long aerated react phase (up to 20 hours) to support ammonia removal. Stirring was maintained at 25 RPM, and DO was kept around 2–4 mg/L. Data were logged every 5 minutes. Temperature was controlled between 28–30°C to suit the microbial source (cow manure from a Waikato dairy farm) used as a biological seed in place of activated sludge. Over a 2-month inoculation period, the SBRs were fed a 1% cow manure solution to cultivate active biomass. Later, ammonium concentration was increased using NH_4Cl to simulate landfill leachate, reaching at least 500 mg/L. The carbon-to-nitrogen ratio (C/N) of the cow manure was measured at 16.44, with moisture content around 87%. The influent was prepared by diluting cow manure in distilled water (up to 5% by mass) and adjusting ammonia levels with NH_4Cl. Influent preparation included filtering solids to protect pumps. This method effectively simulates the

high-ammonia, low-biodegradability conditions of mature landfill leachate.

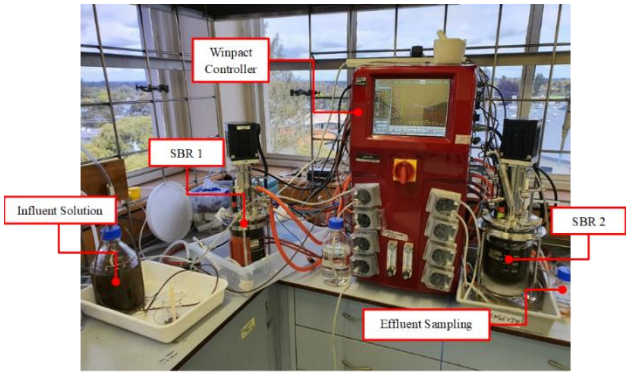

Figure 1. SBR experimental apparatus

3. Results and Discussion

Ammonium concentrations in the influent and effluent of SBR 1 were measured over 250 days using the Palintest method [Palintest, 2018]. Two methods were used to calculate ammonium removal efficiency. The first compared influent and effluent concentrations directly, showing efficiencies mostly between 90–100%. Efficiency, shown in Figure 2, dropped when influent concentrations were 42 mg/L (200 mL dose), 340 mg/L (80 mL dose), and 670 mg/L (40 mL dose), with the lowest removal at 42 mg/L after 108 days, shortly after the ammonium loading was increased. The second method calculated removal by comparing the reactor's ammonium concentration after dosing and before aeration (measured via an ion-selective probe) with the effluent concentration. This more accurately reflected the ammonium removed during treatment. Removal efficiency, shown in Figure 2, within the reactor ranged from 17% to 95%, with greater stability during days 115–154 at influent concentrations of 34–124 mg/L (200 mL doses). Efficiency fluctuated significantly with influent concentrations above 300 mg/L.

Effluent concentrations stayed below 10 mg/L when influent concentration remained under 300 mg/L. Reactor ammonium levels were generally higher than the effluent. Two exceptions, on days 177 and 219, showed temporary increases in effluent ammonium during acclimation to higher influent concentrations.

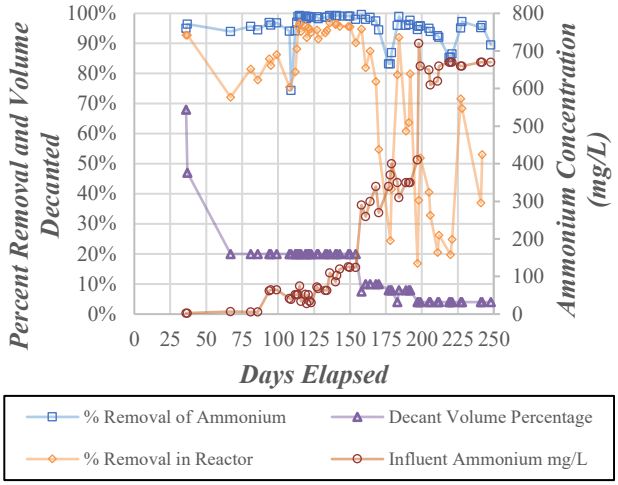

Figure 2. Ammonium removal efficiency

4. Conclusion

This study examined the viability of using on-site SBRs to nitrify the high ammonium concentrations found in landfill leachate in New Zealand. One litre volume SBRs were operated for over 6 months with increasing concentrations of ammonium in the feed to determine ammonium removal. The reactors achieved significant ammonium removal at influent ammonium loading as high as 720 mg/L. pH control was required at higher influent ammonium loadings above 300 mg/L to prevent inhibition of the nitrifying bacteria by acidification. These results suggest that SBR systems can be made a viable option for leachate treatment on-site in New Zealand.

References

Environment Report Card, (2009), Ministry of the Environment. https://environment.govt.nz/assets/Publications/Files/Environmental-Report-Card-Solid-Waste-Composition.pdf

Foo, K.Y. and B.H. Hameed, (2009), An overview of landfill leachate treatment via activated carbon adsorption process. *Journal of Hazardous Materials*, **171**(1): p. 54-60.

Brennan, R.B., et al., (2017) Treatment of landfill leachate in municipal wastewater treatment plants and impacts on effluent ammonium concentrations. *Journal of Environmental Management*. **188**: p. 64-72.

Danley-Thomson, A., et al., (2020) Determining the effects of Class I landfill leachate on biological nutrient removal in wastewater treatment. *Journal of Environmental Management.* **275**: p. 111198.

Iannacone, F., et al., (2019) Effect of carbon-to-nitrogen ratio on simultaneous nitrification denitrification and phosphorus removal in a microaerobic moving bed biofilm reactor. *Journal of Environmental Management,* **250**: p. 109518.

Rizvi, H., et al., (2015), Start-up of UASB reactors treating municipal wastewater and effect of temperature/sludge age and hydraulic retention time (HRT) on its performance. *Arabian Journal of Chemistry*, **8**(6): p. 780-786.

Palintest. (2018). Ammonia. In *Test for ammonia in natural, drinking and waste waters*: Palintest Ltd.