Effect of two different intermediate landfill leachates on ammonium oxidation rate of nitrification bioreactors.

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Due to the ever-growing population and economic growth the annual amount of municipal solid waste (MSW) is rising year by year. The most popular method for disposing MSW is by its deposition in landfills (Miao et al. 2019). In landfills, one of the major emissions are the leachates, which in case of spills can cause hazardous environmental problems such as groundwater pollution. Leachates are formed by the residual or rain water which percolates through the landfilled MSW. These landfill leachates are waste streams characterized by: (i) high composition variability, mainly dependant on waste typology and year season; (ii) high ammonium content; and (iii) presence of toxic and non-biodegradable compounds. This aqueous effluent can be treated by physicochemical or biological methods. However, the previously features make landfill leachates treatment difficult. Despite landfill leachate physicochemical treatments are effective (evaporation, ultrafiltration, coagulation-flocculation, etc.), their high costs and secondary pollution generation promotes the use of biological methods, much more simple and cost-effective (Luo et al. 2019). As a result of its uncommon characteristics, biological processes may not deal with some compounds present in the leachates. An accepted and used indicator to determine leachate biodegradability is the ratio of biological oxygen demand (BOD_5) to chemical oxygen demand (COD). Depending on landfill age, the BOD_5/COD ratio can vary from 0.4 in young (< 5 years old) to 0.1 in old leachates (>10 years old). The most common biological methodology for removing the high ammonium content is by means of nitrification. Due to the high sensibility to xenobiotic compounds of the nitrifying biomass, gaining insights on their ability to degrade ammonium from different ammonium sources is desirable. The bacterial capacity to remove contaminants depends on their origins, so, nitrifying biomass acclimatized to an environment in which landfill leachate is present will be supposed to tolerate better the pollutants present in leachate (Capodici et al. 2019).

Based on the above considerations, the aim of the present work was to elucidate the ability to remove ammonium derived from three different sources (synthetic medium (SM) using NH_4Cl as ammonium source, and two different intermediate landfill leachates (ILL1 and ILL2) with a BOD_5/COD ratio of 0.3 and 0.2, respectively) by three types of gradually adapted nitrifying biomass to these three different ammonium sources: (i) Biomass adapted to synthetic medium (X_{SM}); (ii) Biomass adapted to intermediate landfill leachate 1 (X_{ILL1}) and (iii) Biomass adapted to intermediate leachate 2 (X_{ILL2}). Respirometry was the methodology used to quantify nitritation and nitratation rates at different ammonium concentrations.

Firstly, biomass was obtained from a continuous stirred tank reactor (CSTR) of 5 L (*Applikon Biotechnology BV, The Netherlands*) with biomass recirculation using a settler (1.3 L). After 1 year of working operation maintained at room temperature of 24 ± 2ºC, pH of 7.8 and DO > 2 mg O_2 L^{-1}, the enriched nitrifying biomass X_{SM} was inoculated to two different 1 L sequential batch reactors (SBRs) (*Infors HT, Switzerland*) of which one was progressively fed with ILL1 while the other one was provided with ILL2. After three months of acclimatization at the same operational conditions (24 ± 2ºC, pH =7.8) the nitrification rates of the three different bacterial populations (one from the 5L CSTBR (X_{SM}), and two from the two 1 L SBR (X_{ILL1} and X_{ILL2})) were evaluated in a 1 L respirometer, in which DO, pH and temperature were monitored after substrate addition. After establishing endogenous respiration by keeping the system without substrate for 5 h, the system was aerated until the mixed liquor reaches oxygen saturation concentration. Then, once aeration is stopped, a certain amount of substrate (SM, ILL1 or ILL2) was added to the inoculated bioreactor to different ammonium concentrations ranging from 10 to 5000 mg N-NH_4^+ L^{-1}. After substrate addition, the specific oxygen uptake rate (OUR) was determined at different ammonium concentrations in triplicate. To differentiate between the OUR of ammonium oxidizing bacteria (AOB), nitrite oxidizing bacteria (NOB) and organic matter degrading bacteria, selective inhibitors of NOB and AOB populations as $KClO_3$ and allylthiourea (ATU) were added to the respirometer, respectively.

Fig.1a shows the maximum specific OURs measurements obtained from the different experiments performed when no inhibitors were added. It can be seen that X_{SM}, which has been only fed with SM, achieved the highest specific OURs (210 ± 4.7 mg O_2 TSS^{-1} h^{-1}) which can be directly related to ammonium and nitrite oxidation. These results correlate well with the specific maximum nitritation and nitratation rates of suspended nitrifying biomass obtained by Carrera et al. (2004). Around an average of 5-fold lower OURs were obtained when the different ammonium sources were fed to the respirometers inoculated with X_{ILL1}. The lowest specific OURs were found when X_{ILL2} was supplied with SM and both landfill leachates. An average specific OUR relative reduction of 35 ± 7% was found when $KClO_3$ was added (Fig. 1b), indicating a successful selective inhibition of NOB. Finally, Fig. 1c shows the specific OURs when $KClO_3$ and ATU were added to the respirometer. These data enabled to determine the oxygen consumption by organic matter degrading bacteria present in the three different biomasses. In average, the specific OURs when SM was fed were lower (1.92 ± 0.11 mg O_2 TSS^{-1} h^{-1}) compared to ILL1 (6.37 ± 0.37 mg O_2 TSS^{-1} h^{-1}) and ILL2 (4.98 ± 0.9 mg O_2 TSS^{-1} h^{-1}). From these results it is noticeable that using landfill leachates to feed nitrifying biomass causes a damage on its performance and ability to remove ammonium. Also, the BOD_5/COD ratio seems to have a great influence on acclimatization of bacteria since the ammonium removal capacity of X_{ILL2}, only fed with leachate with lower BOD_5/COD ratio, was significantly lower than the achieved by X_{SM} and X_{ILL1}.

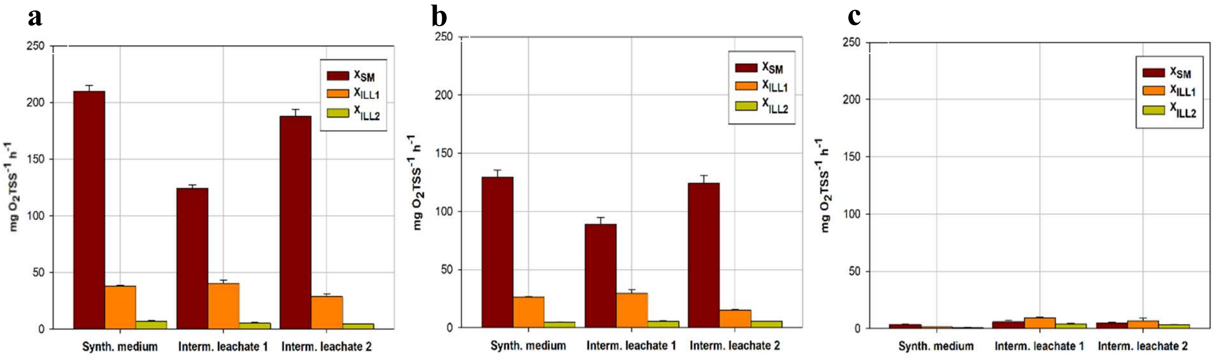

Figure 1. Maximum specific oxygen uptake rate per hour of biomass adapted to synthetic medium (dark red), intermediate landfill leachate 1 (orange) and intermediate landfill leachate 2 (dark yellow) fed with these three different ammonium sources with: (a) no inhibitors; (b) $KClO_3$ and; (c) $KClO_3$ and ATU.

In conclusion, according to the results obtained, the acclimatization process of nitrifying bacteria to two different landfill leachates led to a decrease in ammonium removal ability. Taking into consideration the ammonium removal rates of the acclimatized consortiums, ILL1 is feasible to be biologically treated while ILL2 would need a previous conditioning step.

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