ELAN® technology: a step forward in the quest for energy self-sufficiency in WWTP

A. Val del Río*, N. Morales, J.R. Vázquez-Padín**, R. Fernandez-Gonzalez**, F. Rogalla**, J.L. Campos*, A. Mosquera-Corral*, R. Méndez***

* Department of Chemical Engineering, School of Engineering, University of Santiago de Compostela. E- 15705. Santiago de Compostela, Spain.
** Aqualia (FCC Group), Guillarei WWTP, Camino de la Veiga s/n, E-36720 Tui, Spain.

Keywords: ammonia; anammox; energy self-sufficiency; mainstream; nitrite; temperature

Introduction

The activated sludge process (AS) is still nowadays the most applied one in wastewater treatment plants (WWTP). This technology evolved throughout this last century into multiple configurations to achieve organic matter (COD, BOD_5, etc.) and nutrients (nitrogen and phosphorous) removal. However, the severe increases of energy and sludge management costs registered in the last decades are boosting the research in the quest for more sustainable and efficient processes. The energetic demand of the AS, when nitrogen removal is required, varies typically in the range from 0.5 to 1.4 kWh/m^3 of treated water (Lazarova et al., 2012). The AS is based on aeration to catalyse biological processes and it does not take advantage of the potential energy contained in the organic matter present in the wastewater. The energetic potential of every kilogram of organic matter oxidized (as COD) is about 4 kWh (Garrido et al., 2013). Considering 250 litres of wastewater and 60 g of organic matter (as BOD_5) per inhabitant equivalent and day, about 1 kWh/m^3 of wastewater could potentially be produced.

In order to profit from this potential energy production the future of the wastewater treatment should be focused on anaerobic processes, for both organic matter and nitrogen removal. These processes present higher efficiency and sustainability in terms of biomass growth (the yields are at least one order of magnitude lower) and energy requirements compared to aerobic ones. The energy will be produced by anaerobic digestion of the organic matter. For the nitrogen removal the discovery of anammox bacteria in the nineties opened the possibility to shortcut the nitrogen cycle which involved the decrease of oxygen requirements due to the partial nitrification of half of the ammonium to nitrite while organic matter is not required for denitrification. The company aqualia GIA with the know-how of the University of Santiago de Compostela (USC) developed the so called ELAN® process which performs autotrophic nitrogen removal in a single granular biomass sequencing batch reactor (SBR) (Vazquez-Padin et al, in press).

Around 20% of the nitrogen load in municipal WWTP comes from the supernatant of the anaerobic sludge digester. Nitrogen removal rates of 0.5 – 1.0 kg $N/(m^3\ d)$ are achieved when the ELAN® process (Figure 1a) is applied for the treatment of the digester supernatant. The introduction of the ELAN® process in the sludge line is already a mature technology that brings WWTP closer to energy autarky (Siegrist et al., 2008). The next step and challenge will be the direct application of the anaerobic digestion process in the mainstream followed by the ELAN® process (Figure 1b). This treatment strategy will switch the paradigm and transform municipal and industrial WWTP from energy consumers to energy producers. Laboratory and pilot scale reactors are being run in the USC and in Guillarei WWTP respectively, to study the applicability of the autotrophic nitrogen removal ELAN® process (Figure 2) to mainstream conditions, i.e., low temperature and low ammonia concentration.

Material and Methods

At laboratory scale, a SBR of 4 L of volume operated at 15 ºC and fed with ammonia concentrations of 50 mg NH_4^+-N/L. At pilot scale, a SBR of 600 L of volume treated primary settled municipal wastewater with a temperature in the range 15 - 22 ºC and with ammonium concentrations in the range 20 – 50 mg NH_4^+-N/L. The reactors were inoculated with granules from an ELAN® pilot plant fed with the supernatant of the anaerobic sludge digester of Guillarei municipal WWTP (NW Spain). The biomass concentration in the laboratory scale reactor was in average 10 g VSS/L whereas in the pilot plant was of 2 g VSS/L.

Results and Conclusions

Obtained nitrogen removal rates (Figure 3), both at laboratory and pilot scale, experienced a progressive decrease in the long term operation. This can be explained by the fact that the application of the ELAN® technology to wastewaters with low ammonia concentrations and low temperature requires the maintaining of low concentrations of dissolved oxygen (DO) to avoid the occurrence of the nitrite oxidation. The required low DO concentrations might progressively weaken the aerobic layers of the granular sludge populated mainly by ammonia oxidizing bacteria (Figure 2). As a consequence, the share of aerobic volume in the granule would increase. This would favour the development of nitrite oxidizing bacteria and inhibit the anammox bacteria located in the internal layers of the granules. However, the anammox potential of the biomass was not affected along the whole operation since batch experiments revealed that the maximum nitrogen removal capacity of the biomass was as high at the end of the operation as at its start-up (both, at laboratory and at pilot scale). Furthermore, the SBR operation guaranteed the biomass retention along the 150 days of operation as no significant variations in the biomass concentration in the reactors were registered. For these reasons a robust control strategy to avoid nitrite oxidation is a key factor in order to ensure the stability of the autotrophic nitrogen removal process in the mainstream of a municipal WWTP.

Acknowledgement

This work is enclosed in the ITACA project which is funded by the Spanish Ministry of Economy through the CDTI INNPRONTA program. The authors gratefully acknowledge Augas de Galicia and the Administración Hidráulica de Galicia and the staff of the Guillarei WWTP for their collaboration and the University of Vigo for the automatization, control and communication system of the pilot plant.

References

Garrido, J.M., Fdz-Polanco, M. and Fdz-Polanco, F. (2013) Working with energy and mass balances: a conceptual framework to understand the limits of municipal wastewater treatment. *Water Science & Technology*, **67**(10), 2294-2301.

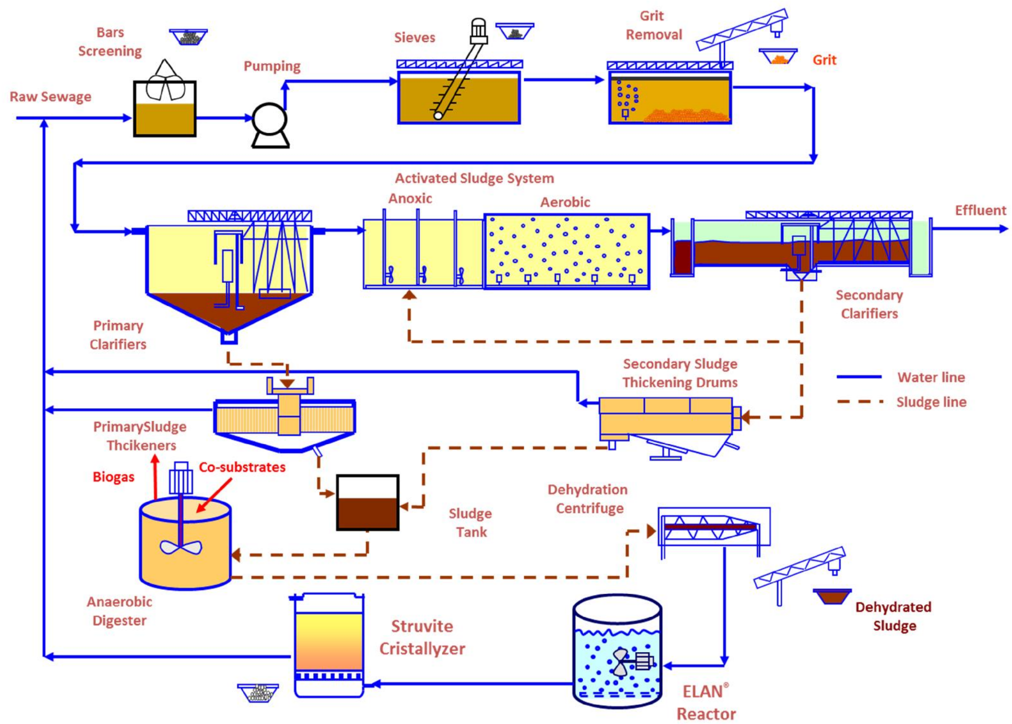
Lazarova, V., Choo K-H. and Cornel P. (2012) Water-energy interactions in water reuse. London; New York, *IWA Publishing*.

Siegrist, H., Salzgeber, D., Eugster, J., and Joss, A. (2008) Anammox brings WWTP closer to energy autarky due to increased biogas production and reduced aeration energy for N-removal. *Water Science &Technology* **57**, 383-388.

Vázquez-Padín, J.R. Morales, N., Gutiérrez, R., Fernández, R., Rogalla, F. , Barrio, J.P., Campos, J.L., Mosquera-Corral, A., Méndez, R. (in press) Implications of full scale implementation of an anammox based process as post-treatment of a municipal anaerobic sludge digester operated with co-digestion. *Water Science & Technology*. doi:10.2166/wst.2013.795.

Figure 1. Schematic representations of next generation WWTP.

a) Improved municipal WWTP



b) The WWTP of the future (for industrial or municipal wastewater)

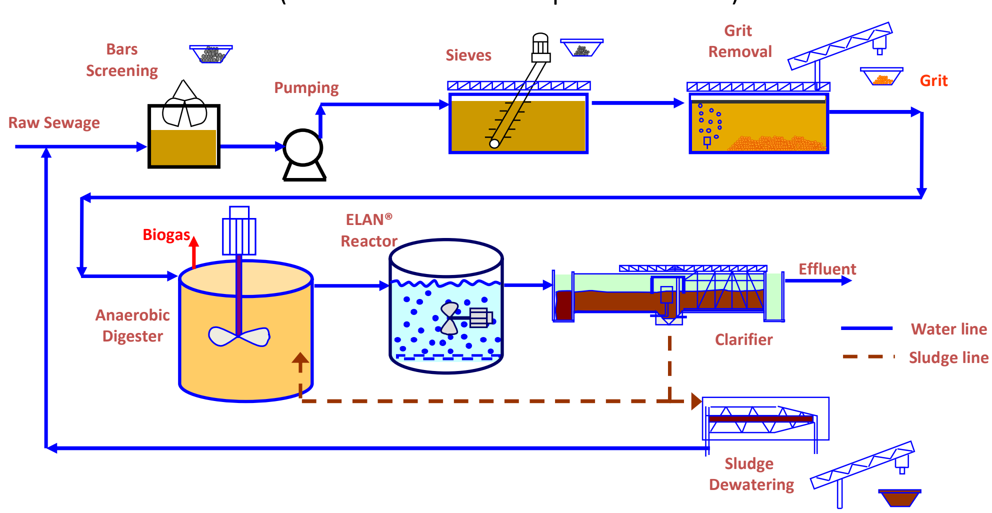


Figure 2. ELAN® process developed by aqualia GIA and the University of Santiago de Compostela.

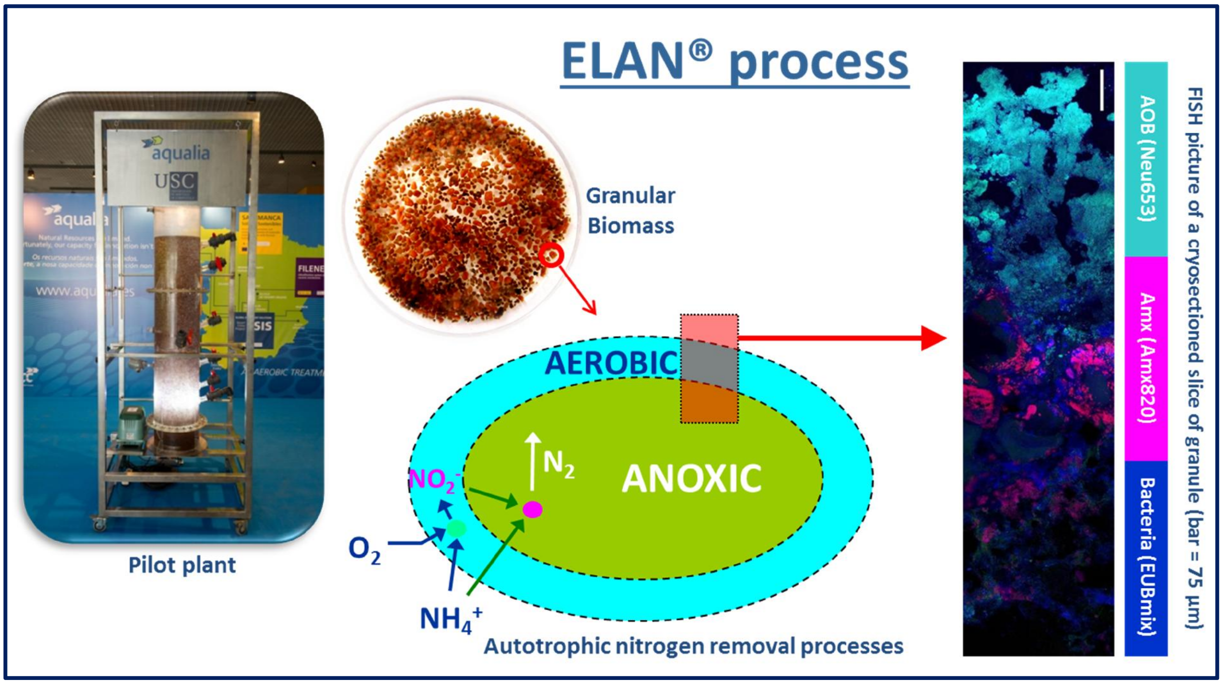


Figure 3. Nitrogen removal rate (ANR, ■), ammonia oxidizing rate (AOR, ▲) and nitrite oxidizing rate (NOR, ○) a) in the laboratory scale reactor and b) in the pilot scale reactor.