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The SND process in two granular sequencing batch reactors with different mean granule sizes: a case study.

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Abstract:	Conventional Activated Sludge plants (CASP) for wastewater treatment have several limitations related to high excess sludge production, large surface area demand and low flexibility. In addition, their upgrading generally involves the use of multiple tanks with the recycling of mixed liquor to obtain high concentrations of microorganisms, nitrates and degradable organics in the anoxic or anaerobic reactors. It also requires additional space that may not be available near the existing treatment plants and, in cases where the space is available, large capital investments are needed in crowded metropolitan areas. For this reason, in recent years the scientific community has been attracted by other innovative systems for wastewater treatment. Among these, the Sequencing Batch Reactor (SBR) with aerobic granular sludge represents a good alternative (Beun et al., 2001 and 2002). The phenomenon of bio-granulation involves cell-cell interaction and includes physical, chemical and biological factors (Adav et al., 2008). The products of this process are the biomass aggregates formed through self-immobilization of micro-organisms. More specifically, the granules are constituted by dense clusters containing millions of organisms per gram, including within them different bacterial species that play different roles in wastewater treatment. Compared to conventional activated sludge flocs, the granules have a smooth texture, thick, strong and very good characteristics of sedimentation. Further, the granular sludge can efficiently operate with high levels of organic load, high hydraulic retention times and variable operational conditions (Yuan and Gao, 2010). Another interesting aspect of this technology is the possibility to obtain a successful removal of nutrients in a single reactor, because the conditions necessary for nitrification, denitrification and biological phosphorus removal are carried-out within the granules (Chen et al., 2011). In fact, the structure of a stable granule can be characterized by different layers, that allow organic carbon and nutrient removal in the same reactor. The presence of heterotrophic population can be observed in the inner part of the granules and, due to oxygen diffusion limitation inside the granules, it is possible to establish a denitrification process; in the middle layer, autotrophic biomass is dominant; in the outer layer, where oxygen and organic substances are highly

available, heterotrophic growth occurs. Nevertheless, the thickness of each layer depends on oxygen and substrate penetration within the granule.
Thus, the Simultaneous-Nitrification-Denitrification (SND) process is regulated by the oxygen gradient within the granule. This depends basically on two aspects: (1) the Dissolved Oxygen (DO) concentration in the bulk liquid; (2) the granule sizes.
In general, there appears to be a general consensus that SND process within the granules can be optimized when a limited oxygen concentration is applied or a specific anoxic phase is performed (Beun et al., 2001). Unfortunately, granules may break with low oxygen concentration and often it is impossible to obtain stable granules.
On the other hand, the granule sizes could have a more important role on the SND process, with reference to thickness variation of anoxic/aerobic zones within the granules. In particular, the different substrate and oxygen penetration inside the granule, during feast and famine periods, can be exploited to improve nutrient removal, also if an high oxygen concentrations is applied. More specifically, granules of appropriate size could provide a good removal of nutrients and organic material without reducing excessively the DO concentration.
In this context, this study analyzes the nutrient removal performance obtained in two SBR reactors with different granular sludge, which differ in their mean granule sizes.
In Figure 1 the pilot plant layout and the geometric characteristics of the reactors are shown.

Figure 1. Pilot plant layout
The study aims to offer useful information about the optimization of nutrient removal in an aerobic granular sludge reactor.
In particular, the data show that the SND process can also occur satisfactorily with high oxygen concentrations. Nevertheless, the specific performance in N-removal was strongly correlated with granule sizes. So, in the future, it would be interesting to investigate this aspect, trying to adjust the DO reduction without compromising the granule stability. In fact, the breakage of the granules worsens the anoxic/anaerobic layer formation.

References
Adav, A.A., Lee D.J., Show, K.Y., Tay, J.H., 2008. Aerobic granular sludge: recent advances, Biotechnol. Adv. 26, 411-423.
Beun, J.J., Heijnen, J.J., van Loosdrecht, M.C.M., 2001. N-removal in a granular sludge sequencing batch airlift reactor, Biotechnol. Bioeng., 75, 82-92.
Beun, J.J., Heijnen, J.J., van Loosdrecht, M.C.M., 2002. Aerobic granulation in a Sequencing Batch Airlift Reactor, Water Res. 36, 702-712.
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Extended Abstract:

Conventional Activated Sludge plants (CASP) for wastewater treatment have several limitations related to high excess sludge production, large surface area demand and low flexibility. In addition, their upgrading generally involves the use of multiple tanks with the recycling of mixed liquor to obtain high concentrations of microorganisms, nitrates and degradable organics in the anoxic or anaerobic reactors. It also requires additional space that may not be available near the existing treatment plants and, in cases where the space is available, large capital investments are needed in crowded metropolitan areas. For this reason, in recent years the scientific community has been attracted by other innovative systems for wastewater treatment. Among these, the Sequencing Batch Reactor (SBR) with aerobic granular sludge represents a good alternative (Beun et al., 2001 and 2002).
The phenomenon of bio-granulation involves cell-cell interaction and includes physical, chemical and biological factors (Adav et al., 2008). The products of this process are the biomass aggregates formed through self-immobilization of micro-organisms. More specifically, the granules are constituted by dense clusters containing millions of organisms per gram, including within them different bacterial species that play different roles in wastewater treatment. Compared to conventional activated sludge flocs, the granules have a smooth texture, thick, strong and very good characteristics of sedimentation. Further, the granular sludge can efficiently operate with high levels of organic load, high hydraulic retention times and variable operational conditions (Yuan and Gao, 2010).
Another interesting aspect of this technology is the possibility to obtain a successful removal of nutrients in a single reactor, because the conditions necessary for nitrification, denitrification and biological phosphorus removal are carried-out within the granules (Chen et al., 2011). In fact, the structure of a stable granule can be characterized by different layers, that allow organic carbon and nutrient removal in the same reactor. The presence of heterotrophic population can be observed in the inner part of the granules and, due to oxygen diffusion limitation inside the granules, it is possible to establish a denitrification process; in the middle layer, autotrophic biomass is dominant; in the outer layer, where oxygen and organic substances are highly available, heterotrophic growth occurs. Nevertheless, the thickness of each layer depends on oxygen and substrate penetration within the granule.

Thus, the Simultaneous-Nitrification-Denitrification (SND) process is regulated by the oxygen gradient within the granule. This depends basically on two aspects: (1) the Dissolved Oxygen (DO) concentration in the bulk liquid; (2) the granule sizes.
In general, there appears to be a general consensus that SND process within the granules can be optimized when a limited oxygen concentration is applied or a specific anoxic phase is performed (Beun et al., 2001). Unfortunately, granules may break with low oxygen concentration and often it is impossible to obtain stable granules.
On the other hand, the granule sizes could have a more important role on the SND process, with reference to thickness variation of anoxic/aerobic zones within the granules. In particular, the different substrate and oxygen penetration inside the granule, during feast and famine periods, can be exploited to improve nutrient removal, also if an high oxygen concentrations is applied. More specifically, granules of appropriate size could provide a good removal of nutrients and organic material without reducing excessively the DO concentration.
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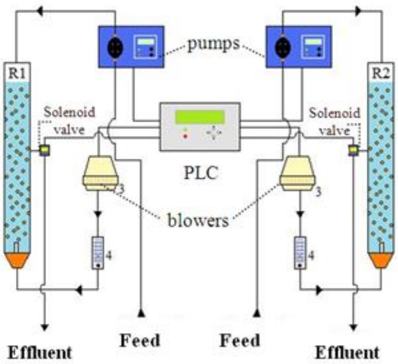

Geometric features of the reactors	SBAR	SBBC	Unit
cylinder height	860	860	mm
riser height	600	-	mm
water table level	690	640	mm
cylinder diameter	90	90	mm
riser diameter	54	-	mm
volumetric exchange ratio	50	50	%
Reactor volume	3.5	3.5	litri

Figure 1. Pilot plant layout

The study aims to offer useful information about the optimization of nutrient removal in an aerobic granular sludge reactor.
In particular, the data show that the SND process can also occur satisfactorily with high oxygen concentrations. Nevertheless, the specific performance in N-removal was strongly correlated with granule sizes. So, in the future, it would be interesting to investigate this aspect, trying to adjust the DO reduction without compromising the granule stability. In fact, the breakage of the granules worsens the anoxic/anaerobic layer formation.

References

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