Integrating Advanced Primary Treatment with Aerobic Granular Sludge

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Introduction:

Wastewater treatment plants (WWTP) are facing increasing demands to reduce energy consumption and footprint requirements while maintaining compliance with stringent nutrient discharge limits. Aerobic Granular Sludge (AGS) has emerged as an innovative treatment technology capable of effective nutrient removal with greatly reduced aeration and footprint requirements when compared to conventional activated sludge systems (CAS). Advanced Primary Treatment (APT) is another innovative technology that replaces conventional primary treatment (CPT) with compact cloth disk filters. APT has been shown to have superior total suspended solids (TSS) and chemical oxygen demand (COD) removal than CPT, have a smaller footprint, and potentially reduce aeration requirements in the subsequent biological treatment due to reduced organic loading. While both technologies have been demonstrated to be effective at the pilot and full-scale (Caliskaner et al. 2021; Ekholm et al. 2023), combining these two intensification processes and their holistic impact on each other has not been explored. As a result, this paper aimed to evaluate and model the performance, aeration savings, and footprint savings of integrating APT prior to AGS.

Methods:

In this study, two Aqua-Nereda AGS pilot reactors were operated over a year and were fed with either CPT (Reactor B) or APT (Reactor A) effluent. Both reactors ran with 4-hour cycle including: 1-hour simultaneous feed and decant, 2.5-hour reaction, and 0.5 hour settling periods. The reactors were operated under low DO conditions and utilized an ammonia setpoint to distinguish between aerobic and anoxic reaction periods. Several oxygen transfer efficiency tests were conducted to determine the alpha value associated with each reactor. The removal performance and aeration requirements were used to calibrate two computer models built in the software SUMO (Dynamita). The calibrated pilot-scale models were then used to predict aeration and footprint savings if the proposed CPT + AGS or APT + AGS treatment trains were implemented at the Linda County WWTP (CA, U.S.), where the pilot study was conducted. A previously built full capacity (10 MGD) model of the Linda County WWTP was used for comparison.

Results:
The performance of the cloth disk filter was consistent with other full-scale studies that utilized the same treatment system (Caliskaner et al. 2021). The average TSS and VSS effluent concentrations of the APT system were 46 mg/L (43% lower than CPT) and 38 mg/L (47% lower than CPT), respectively .

The performance between Reactor's A and B showed no significant differences in nitrogen removal. Inhibited denitrification activity is often a concern for APT effluent due to the enhanced organic carbon removal. However, no significant variation in NO_3 removal was observed. Additionally, the APT effluent-fed AGS reactor only used a cumulative daily average air flow of 18 m^3/d, compared to 27 m^3/d for the CPT effluent-fed reactor. Both reactors achieved the same level of ammonia removal. The average alpha value for both reactors was 0.45, lower than what is typically seen in full-scale applications.

Calibration of the pilot-scale systems in SUMO was mainly related to NO_3 performance, as the default kinetic parameters had good agreement with COD, NH_3, and TSS concentrations. The reduction factor for ordinary heterotrophs growth under anoxic conditions was adjusted to match the measured NO_x concentrations. Phosphorus species were not calibrated and considered to beyond the scope of this paper. The model revealed more insight into the aeration savings seen in the pilot study. By lowering the organic loading, nitrification occurred faster in Reactor A, and the ammonia threshold was reached sooner. As a result, the air requirement was lower, and the subsequent anoxic phase was longer. Better NO_3 removal was achieved. The low alpha value was used for model calibration, but it should be noted that the modeled aeration savings seen by the addition of AGS could be much higher based upon full-scale AGS testing (de los Santos, et al., 2020).

For the full-scale simulations, the applications of CPT + AGS and APT + AGS showed a 7% and 12% decrease in aeration requirements when compared to the modeled CAS system with similar performance. Other full-scale AGS applications have seen higher aeration savings (Pronk et al. 2015), and the difference can be attributed to the conservative alpha value determined from the pilot testing. Beyond aeration, the AGS + APT treatment trains also reduced the footprint requirements by 42% when compared to CAS.

Significance:

The results of the study demonstrate the benefits of combining APT with AGS, and the treatment train may be considered by practitioners facing extreme footprint and effluent quality restrictions. Neither the oxygen transfer efficiency nor denitrification rate of the AGS reactor was negatively affected by upstream primary filtration which removes more organics prior to the secondary treatment. At the pilot scale, the AGS reactor that was fed APT used nearly 50% less air than its counterpart. The full-scale model of APT + AGS resulted in a reduction of 11% and 42% for aeration and

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