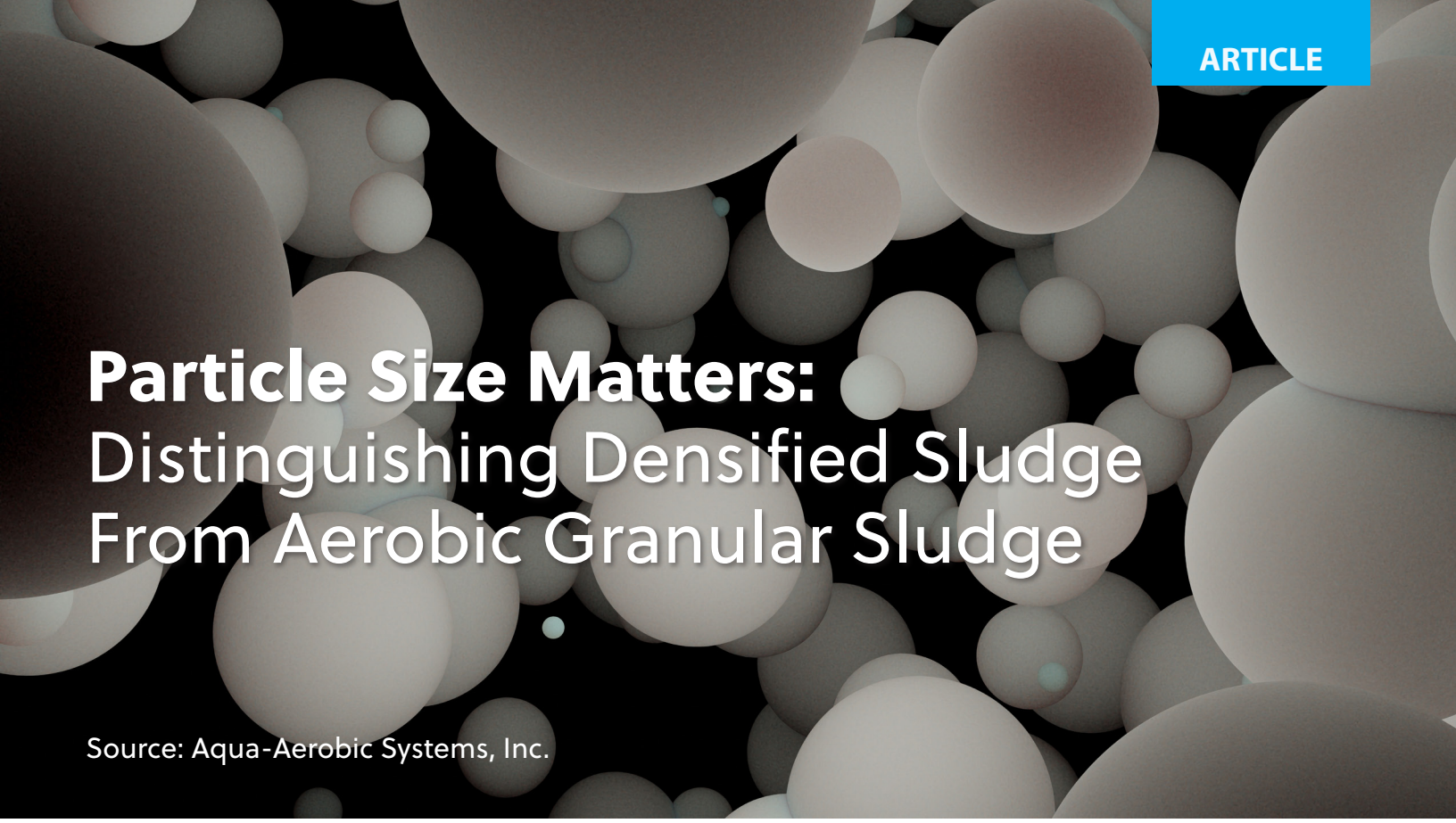
ARTICLE

Particle Size Matters: Distinguishing Densified Sludge From Aerobic Granular Sludge



Source: Aqua-Aerobic Systems, Inc.

As flow rates increase and nutrient requirements tighten, many wastewater treatment plants (WWTPs) are looking beyond conventional activated sludge (CAS) toward process intensification technologies such as aerobic granular sludge (AGS) and densified activated sludge (DAS). These technologies work by introducing physical and biological selection pressure to create larger sludge particles that settle faster, support higher mixed liquor concentrations, and enhance nitrogen and phosphorus removal.

While the benefits of process intensification overall are well known, the characteristics of each approach may be less clear. DAS and AGS are distinct technologies with their own sludge structural properties, settling characteristics, and applications. Understanding those differences can help engineers and plant managers know what type of system they are getting and what performance to expect.

Physical Criteria & Operational Parameters

Particle size itself is the primary characteristic that distinguishes DAS from AGS. DAS is largely defined by an average particle size under 400 µm in diameter, with a range of dense flocs ranging from 200 to 600 µm. By comparison, AGS is recognized for having a broader particle size distribution, averaging above 600 µm overall, with mature granules reaching up to 3 mm.

When engineered correctly, a system can operate with these denser particle sizes that increase mixed liquor concentrations and decrease settling times. DAS, for example, operates reliably at 5,000 to 5,500 mg/L mixed liquor suspended solids (MLSS). Even at peak concentration, the system should target a preferred SVI30 of approximately 60 to 80 mL/g. Meanwhile AGS systems are designed for high-density operations of over 8,000 mg/L MLSS, while maintaining an SVI30 target of 40 to 60 mL/g or even less at peak MLSS concentrations.

Different particle sizes play different roles in the treatment process. For example, dense particles under 400 µm remain mostly aerobic throughout their structure, supporting bacteria with high specific nitrification rates. Moderately sized granules (~1 mm) have well-defined internal anoxic gradients that enable simultaneous nitrification-denitrification (SND) and biological phosphorus removal. Large granules (2 to 3 mm) provide rapid settling velocities and greater physical robustness. Phosphate-accumulating organisms (PAOs) grow around the core of these larger particles, forming an outer shell of extracellular polymeric substances (EPS).

Biological Mechanisms

While each intensification process is distinct, they rely on the same biological selection mechanisms. Both technologies utilize time-based batch control based on a sequencing batch reactor (SBR) framework. This feature provides precise control over influent contact timing, creating reproducible, optimized feast-famine conditions batch after batch.

Furthermore, selective wasting of lighter flocs is used to favor slow-growing, denser biomass, including polyphosphate-accumulating organisms and glycogen-accumulating organisms. Meanwhile, biodegradable organic carbon is brought

into direct contact with the biomass under anaerobic conditions.

It is important to note that the combination of both selection mechanisms sets these technologies apart. Without the feast-famine conditions, selective wasting alone may select for heavier particles but will not select for the actual particles that produce granular or densified sludge.

The primary difference is in the process design. AGS applies all the selection pressures at full strength: strict feast-famine conditions, selective feeding, and selective wasting of slow-settling flocs. This lets biomass grow into true granules. DAS applies these pressures more moderately. It improves density and settling, but the sludge stays closer to a floc than a granule.

Economics & Applications

Both DAS and AGS offer increased treatment capacity and improved nutrient removal. The question of which technology is best suited to an application depends on the required capacity increase, capital budget, and site footprint. DAS serves as a cost-effective option for incremental capacity upgrades, typically less than a twofold expansion. It is also ideal for retrofitting existing SBRs. With less overall equipment and simpler tank conversion, DAS has a lower upfront capital expenditure than AGS, while still delivering improved performance over CAS.

AGS, on the other hand, is best suited for greenfield developments, sites facing extreme footprint limitations, or major retrofits requiring more than double the current capacity. Overall, AGS often proves more economical for large expansions because its high biomass density drastically reduces the total basin volume and construction footprint.

While both technologies offer distinct operational expense (OpEx) benefits, AGS offers more pronounced long-term savings. An AGS facility can reduce energy demands by eliminating mechanical mixers and requiring minimal pumping. Staggered reactor cycles allow the system to share a common blower air pool, flattening peak power demands. In addition, AGS can achieve biological phosphorus removal with minimal chemical dosing and recovers supplemental alkalinity through simultaneous denitrification, which is particularly beneficial for plants treating low-alkalinity wastewater. Granular waste sludge also boasts improved dewatering, with some plants seeing up to a 20% reduction in polymer consumption and increased dry cake solids.

The choice between DAS and AGS boils down to the demands of the specific application. However, it is critical that WWTP managers and consulting engineers understand not just the difference between the technologies but how to ensure that they are getting the system they want. By recognizing that particle size dictates both biological capability and physical performance, plant operators can match the right intensification technology to their specific regulatory and site constraints. ■