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Understanding the effects of nutrient removal on dewatering

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As states push nutrient discharge limits lower for water resource recovery facilities (WRRFs), utilities must implement different technologies to make sure they comply. While many different nitrogen (N) and phosphorus (P) removal technologies can help meet these limits, WRRFs must carefully select them to avoid unintended consequences on dewatering processes and costs.

Nitrogen removal

When it comes to N removal from waste streams, two methods are typically used, physicochemical (ion exchange, air stripping, etc.) and biological. Although both methods can remove nutrient, biological nutrient removal often makes more fiscal sense.

By using the natural nitrogen cycle of the bacteria in a WRRF, nitrogen is removed via nitrification–denitrification. Ammonia is transformed to nitrite (NO_2^-) and then nitrate (NO_3^-) during nitrification before a different set of bacteria transforms nitrate into nitrogen gas (N_2) during denitrification. The gas escapes into the atmosphere.

The entire process is driven by bacteria under either anaerobic or aerobic conditions. Oftentimes, these processes occur in separate tanks as nitrification is an aerobic process while denitrification is an aerobic process, but it can all be completed in one tank if anaerobic zones exist. Aside from aeration, nitrification–denitrification requires ample carbon for the bacteria to use as building blocks. Optimization of the process, important to achieve high removal, requires balancing temperature, dissolved oxygen, pH, and solids retention time. As shown in Figure 1 (p. xx), balancing carbon also is important. The carbon used for nutrient removal lessens the amount available for anaerobic digestion to generate biogas, and therefore, energy.

Phosphorus removal

Phosphorus removal presents a different challenge. Unlike N, P cannot be removed as a gas; instead, it must be removed as a solid. Many methods can remove P such as chemical, biological, combined chemical and biological and nano processes. Membrane filtration, including reverse osmosis, nanofiltration, and electrodialysis reversal all fall under the nano process category. Chemical methods rely on such chemicals as alum or ferric chloride to bind to phosphorus and precipitate it out as a solid, which can be collected. The quality and type of phosphorus precipitate is dictated by optimizing wastewater pH, chemical addition, mixing, and other factors.

Biological P removal uses anaerobic conditions followed by aerobic conditions to promote P uptake by phosphorus accumulating organisms (PAOs). Anaerobic conditions promote the consumption of volatile fatty acids (VFAs) by the PAOs, which forces them to release phosphorus. Once the PAOs switch to aerobic conditions, they uptake the released phosphorus as they replenish stores and multiply, resulting in more P removed than was released. The phosphorus-rich PAOs are then removed as settled solids, resulting in a low phosphorus liquid wastewater effluent.

Effects on dewatering

It turns out that N and P removal also effect solids dewatering quite a lot. Figure 2 (p. xx) shows that nutrient removal can hinder dewatering. This means using more polymer to get the same dewatering results; and increased costs for one of the most cost-intensive parts of treatment. A decrease in solids dewaterability by as much as 6% total solids leads to 2 to 3 times the polymer needed. Decreased dewaterability also means more cost to haul away the solids to landfills or composting or more fuel needed to incinerate the solids.

Nutrient removal in and of itself isn't the cause of poor dewatering performance as some methods such as nitrification–denitrification have no negligible effect. Studies and real-world performance show that specific types of phosphorus removal can directly affect dewatering. For example, chemical P removal can help with dewatering, while biological P removal hinders it.

When biological phosphorus removal is combined with anaerobic digestion and low-metal ions (iron and aluminum), dewatering efficiency decreases. This causes higher polymer demand and, therefore, increased costs. (See Figure 3, p. xx.)

Other studies have investigated the effect of biological phosphorus removal on dewatering and identified extracellular polymeric substances (EPS) as the culprit. EPS are released by anaerobic microbial communities. Dewatering decreased as the EPS content increased after anaerobic digestion, showing a correlation between the two and leading researchers to conclude that removing EPS may increase dewaterability.

Anaerobic digestion followed by aerobic treatment, using zero valent ions and other technologies has minimal effects on dewaterability.

The research is not completely settled, and it is up to WRRFs to investigate the wide range of nutrient removal technologies available and see which can help meet their goals while maintaining high dewaterability.

Balancing the scales

N and P removal are necessary for WRRFs to meet discharge limits and keep our environment safe and healthy. However, tradeoffs exist, such as the effects these technologies can have on dewatering. Each of these financial and operational implications must be considered. Each WRRF is a unique system and nutrient removal technologies must be chosen based on a such factors as influent flow and loading, economic considerations, and permit limits.

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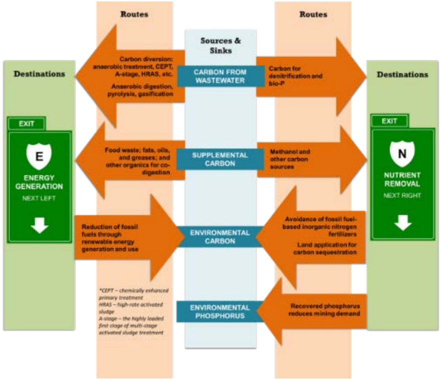
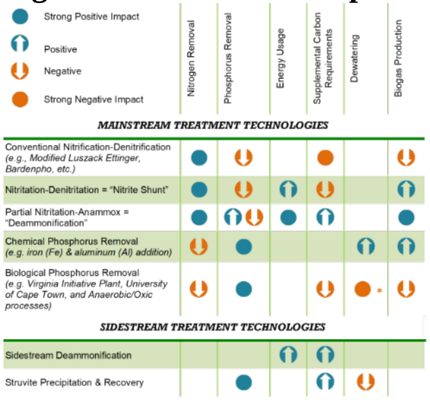
Figure 1. Both energy generation and nutrient removal require carbon



[File: Nutrients-dewatering - fig 1.png]

Figure 2. Interrelationships between N and P removal and other WRRF operations



🔵 Strong Positive Impact

⬆ Positive

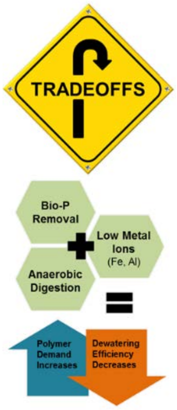
⬇ Negative

🟠 Strong Negative Impact

	Nitrogen Removal	Phosphorus Removal	Energy Usage	Supplemental Carbon Requirements	Dewatering	Biogas Production
MAINSTREAM TREATMENT TECHNOLOGIES						
Conventional Nitrification-Denitrification *(e.g., Modified Luszack Ettinger, Bardenpho, etc.)*	🔵	⬇		🟠		⬇
Nitritation-Denitritation = "Nitrite Shunt"	🔵	⬇	⬆	⬇		⬆
Partial Nitritation-Anammox = "Deammonification"	🔵	⬆⬇	🔵	⬆		🔵
Chemical Phosphorus Removal *(e.g. iron (Fe) & aluminum (Al) addition)*	⬇	🔵			⬆	⬆
Biological Phosphorus Removal *(e.g. Virginia Initiative Plant, University of Cape Town, and Anaerobic/Oxic processes)*	⬇	🔵		⬇	🟠 *	⬇
SIDESTREAM TREATMENT TECHNOLOGIES						
Sidestream Deammonification			⬆	⬆		
Struvite Precipitation & Recovery		🔵		⬆	⬇	

[File: Nutrients-dewatering - fig 2.png]

Figure 3. Biological phosphorus removal increases dewatering polymer demands



[File: Nutrients-dewatering - fig 3.png]