Membrane thickening aerobic digestion processes

Bryen Woo

ABSTRACT

Sludge management accounts for approximately 60% of the total wastewater treatment plant expenditure and laws for sludge disposal are becoming increasingly stringent, therefore much consideration is required when designing a solids handling process. A membrane thickening aerobic digestion process integrates a controlled aerobic digestion process with pre-thickening waste activated sludge using membrane technology. This process typically features an anoxic tank, an aerated membrane thickener operating in loop with a first-stage digester followed by second-stage digestion. Membrane thickening aerobic digestion processes can handle sludge from any liquid treatment process and is best for facilities obligated to meet low total phosphorus and nitrogen discharge limits. Membrane thickening aerobic digestion processes offer many advantages including: producing a reusable quality permeate with minimal levels of total phosphorus and nitrogen that can be recycled to the head works of a plant, protecting the performance of a biological nutrient removal liquid treatment process without requiring chemical addition, providing reliable thickening up to 4% solids concentration without the use of polymers or attention to decanting, increasing sludge storage capacities in existing tanks, minimizing the footprint of new tanks, reducing disposal costs, and providing Class B stabilization.

Key words | aerobic digestion, membranes, nutrients, solids handling

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INTRODUCTION

All wastewater facilities generate solids and therefore dealing with solids is essential. The processing, treatment, and disposal of sludge for beneficial use accounts for approximately 40–60% of total wastewater treatment plant (WWTP) expenditures. These costs will only continue to rise because the amount of sludge produced at WWTPs is continually increasing. The United States Environmental Protection Agency (US EPA) estimated the sewage sludge production from publicly owned treated works facilities in the United States was 6.3 million dry tonnes in 1998 (US EPA 1999) and 7.3 million dry tonnes in 2005 (US EPA 2006). Depending on economic factors, site conditions, regulatory requirements, stabilization goals, and solids disposal options, there are many solids handling technologies WWTPs can consider before determining the appropriate solution.

A membrane thickening aerobic digestion process is a controlled aerobic digestion process that utilizes a membrane for thickening waste activated sludge (WAS) that consistently provides reliable and improved thickening performance and sustainable nutrient management of a biosolids handling process by minimizing total nitrogen and phosphorus loading in side stream flows. A side stream is any process flow resulting from the treatment of biosolids that flows back to the liquid treatment process, and can account for approximately 20% of a WWTP's total influent nitrogen and 30% of the total influent phosphorus load (Bilyk *et al*. 2011). Examples of side streams are filtrate or centrate from dewatering operations and supernatant from digestion processes. If a plant recycles very high concentrations of nitrogen and phosphorus in the side streams of solids handing processes it can be difficult to remove in the biological process, making it problematic to comply with any discharge permit requirements.

This process is suitable for handling WAS from many liquid treatment processes such as a membrane bioreactor (MBR) and also conventional processes such as sequencing batch reactor (SBR), extended aeration such as an oxidation ditch, rotating biological contactors (RBC), and activated sludge processes such as a modified Ludzack-Ettinger (MLE).

Membranes are typically utilized in liquid treatment applications such as an MBR process, therefore using membranes to pre-thicken sludge in an aerobic digestion process is a unique approach. Although a membrane thickening

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aerobic digestion process is a relatively new solids handling approach to many, it uses the same membrane equipment as an MBR process but thickens the sludge to three times greater concentration. This process offers outstanding operational, economic, and process benefits that include: the ability to reliably thicken sludge up to 4% solids concentration without the use of polymers or operator attention, providing a Class B stabilized sludge with a reduced tank footprint, optimizing digestion performance, reducing sludge disposal, and producing a reuse quality permeate, effectively minimizing the impact of nutrients from solids-handling side streams on a liquid treatment process. This process also provides continuous thickening, allowing for operations to be independent of wasting schedules from the liquid treatment process. Currently, there are 16 operating membrane thickening aerobic digestion process installations in the USA, with several more in construction. The hydraulic flow of these plants is typically between 1,893 m^3 per day and 7,571 m^3 per day, with one installation designed for a 94,635 m^3 per day flow.

METHODOLOGY: DESCRIPTION OF THE MEMBRANE THICKENING AEROBIC DIGESTION PROCESS

The steps of the membrane thickening aerobic digestion process are shown in Figure 1 and described below.

1. WAS is wasted from the activated sludge process and enters the anoxic tank at a rate of 1 Q (the influent waste activated sludge flow rate).
2. As the liquid level in the anoxic tank rises, sludge is pumped into the membrane thickening tank (MBT) at a recycle rate of 4 Q, ensuring the solids remain at an optimum thickness.

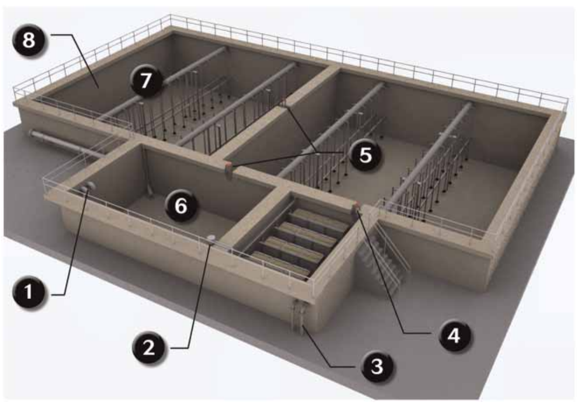

Figure 1 | General membrane thickening aerobic digestion process.

3. As WAS is pumped into the MBT from the anoxic tank, permeate is extracted through the membranes and either goes to the head of the plant or to disinfection.
4. When the maximum liquid level in the MBT is reached, the addition of sludge to this tank causes a corresponding overflow into the in-loop digester for first-stage digestion.
5. When the maximum liquid level in the in-loop digester is reached, the addition of sludge to this tank will cause a corresponding overflow of sludge to either the isolation-digester or to the anoxic tank, completing a continuous process loop.
6. Nitrified sludge transferred from the in-loop digester to the anoxic tank is mixed with the incoming WAS, which serves as a fresh carbon source thus allowing for denitrification without having to cycle the air on and off in the digester tanks.
7. The small portion of sludge that is transferred from the in-loop digester to the isolation digester is aerated and mixed for second-stage digestion for further pathogen removal.
8. Sludge is transferred out of the isolation digester tank for final disposal.

As described above, a membrane thickening aerobic digestion process utilizes a nitrification and denitrification process that removes nitrogen in both the solid and liquid phases.

Phosphorus removal presents a much more challenging and sophisticated concept in the membrane thickening aerobic digestion process than nitrogen removal. A membrane thickening aerobic digestion process is capable of minimizing the release of the three forms phosphorus: inorganic phosphorus, polyphosphorus, and organic phosphorus.

Although phosphorus is generally not soluble in water, aqueous phosphates are commonly found in wastewater. Under acidic conditions H^+ ions are present phosphate (PO_4^{-3}) and can be transformed into aqueous forms of hydrogen phosphate (HPO_4^{-2}), dihydrogen phosphate (H_2PO_4), and phosphoric acid (H_3PO_4). The dissolution of inorganic phosphorus is controlled by pH and described using the acid disassociation equilibrium constant (pK_a). Phosphoric acid is triprotic, therefore the pK_a values of hydrogen phosphate, dihydrogen phosphate, and phosphoric acid are 12.7, 7.2, and 2.12 respectively (Ju *et al.* 2005). Under pH conditions between 12.7 and 7.2, hydrogen phosphate and dihydrogen phosphate species are most common, and can form bonds with minerals such as calcium, sodium,

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and magnesium. The compounds formed with these minerals and aqueous phosphate species form precipitates that remove phosphorus from the solution to the solids. Under acidic conditions phosphoric acid is the dominant species and cannot form bonds with minerals or metals so the phosphorus stays in aqueous form. The continuous nitrification and denitrification sequencing described above in the membrane thickening aerobic digestion process allows excellent pH control, preventing the dissolution of inorganic phosphorus by maintaining the pH at 6.0–7.5.

Polyphosphorus-accumulating organisms (PAOs) can store carbon compounds as a source of energy in the absence of oxygen or nitrate, which are common energy sources in biological processes. The storage of carbon compounds by PAOs results in a polyphosphorus release. The incoming WAS into the anoxic tank provides a fresh carbon source for PAOs to release polyphosphate following the exhaustion of nitrate, which also occurs in this tank. The aerated MBT where permeate is collected, allows for the PAOs to grow and takeup the released polyphosphorus while their stored carbon reserves are oxidized, resulting in reduced phosphorus levels in permeate.

PAO decay causes organic phosphorus release into the permeate due to substantial biomass destruction in the membrane thickening aerobic digestion process. However, organic phosphorus release in permeate is minimal since Van Haandel and Van der Lubbe found the decay rate of PAO is approximately six times slower than non-PAO bacteria, and there are approximately twice as many non-PAO bacteria than PAO in typical biomass. Although non-PAO bacteria are more common in biomass and have a faster decay rate, they contain approximately fifteen times less polyphosphorus than PAO bacteria (Van Haandel & Van der Lubbe 2007).

DISCUSSION: EVALUATING THE KEY ADVANTAGES OF A MEMBRANE THICKENING PROCESS

Improved thickening without the use of polymers or decanting

Membrane thickening aerobic digestion processes produces a Class B stabilized sludge with reliable thickening without using polymers or decanting, allowing wastewater facilities to expand solids storage capacity in existing process tanks and minimizing the footprint of newly constructed tanks. According to the US EPA, Class B sludge is stabilized where pathogens are significantly reduced but still present in large numbers. Class B sludge can be used for application to agricultural or nonagricultural land. In order to meet Class B stabilization, two criteria must be met as per the EPA Title 40 – CFR Part 503 regulations. The first criterion that must be met is pathogen reduction and this can be met by complying with one of these two requirements: (1) pathogens in the sewage sludge containing less than 2,000,000 colony-forming units (CFU) per gram of total dry solids and (2) meeting a time temperature requirement of 20 °C at 40 days' sludge retention time (SRT) or 15 °C at 60 days' SRT. The second criterion is the vector attraction and can be met by meeting one of these two requirements: (1) volatile solids reduction of 38% or more or (2) standard oxygen uptake rate (SOUR) of 1.5 milligrams oxygen per hour per gram of total solids (mg O_2/g TS/h) or less (US EPA 1993). For example, if a sludge sample has a SOUR of 1.49 mg O_2/g TS/h and pathogens of 1,999,999 CFU per gram of total solids then it is in compliance with Class B stabilization requirements.

Thickening with membranes is independent of the WAS settling characteristics, in contrast to a standard aerobic digestion process where WAS is aerated in one or more tanks and periodically aeration is stopped to allow the WAS to settle and excess liquid to be decanted. However, thickening performance can fluctuate greatly and can have high disposal costs, especially without sludge dewatering. Sludge concentration of WAS in aerobic digestion operations can range from 0.8 to 2.5% but is typically 1.3% (Burton & Tchobanoglous 1991). Membranes are capable of thickening WAS up to 4% because the higher solids concentration is a function of physically filtering permeate out of the sludge rather than relying on gravitational settling. Comparing membrane thickening to a standard aerobic digestion process that utilizes decanting to thicken WAS, membranes provide more than three times the thickening performance if typical solids concentrations are considered.

Many wastewater operators find dealing with polymers difficult and labor intensive. Membrane thickening aerobic digestion processes do not require any polymers for thickening and therefore substantially minimizes operator attention while thickening. It eliminates maintenance associated with polymer thickening such as start up, cleanup, and shut down time of mechanical equipment.

Thickening of WAS with membranes also brings much value to a wastewater treatment facility such as reduced disposal, energy, operation and maintenance costs and the construction costs of process tanks. Reliable and improved thickening with membranes significantly reduces the volume of sludge, minimizing the footprint of process

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Table 1 | Evaluation of solids-handling processes considered for Plant A

Design conditions		
Class B biosolids		
Mixing air requirement of 30 m^3/min/1,000 m^3		
Process air requirement of 2 kg O_2/kg volatile solids (VS) destroyed		
15-year life cycle		
Sludge is dewatered with belt press to 16% cake solids and land applied		
Design parameters		
Plant flow m^3/day	15,142	
Biochemical oxygen demand (BOD) concentration (mg/L)	250	
Sludge yield (kg WAS/kg BOD)	0.7	
WAS loading rate (kg/day)	2,654	
Required SRT (days)	42	
Standard aerobic digestion process design		
WAS concentration (%)	2%	
WAS volume (m^3/day)	132	
Volume required (m^3)	5,565	
Airflow required (m^3/min)	167	
Annual energy consumption (kWh)	1,871,486	
Concrete required for process tanks (m^3)	1,012	Concrete costs are $654/$m^3$
Membrane thickening aerobic digestion process design		
WAS concentration (%)	4%	
WAS volume (m^3/day)	66	
Volume required (m^3)	2,783	
Airflow required (m^3/min)	113	
Annual energy consumption (kWh)	1,390,247	
Concrete required for process tanks (m^3)	532	Concrete costs are $654/$m^3$
Mechanical thickening aerobic digestion process design		
WAS concentration (%)	5%	
WAS volume (m^3/day)	53	
Volume required (m^3)	2,226	
Airflow required (m^3/min)	130	
Annual energy consumption (kWh)	1,383,563	
Concrete required for process tanks (m^3)	519	Concrete costs are $654/$m^3$
15-year life cycle cost comparisons		
Membrane thickening aerobic digestion		
Capital	$1,147,500	Includes equipment, building, and process tank costs
Operating	$256,500	Includes chemical and operating costs
Disposal	$989,697	Based on $11.40/tonne and $1.80/kg polymer
Energy	$1,459,759	Based on $0.07/kWh

(*continued*)

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Table 1 | continued

15-year life cycle cost comparisons		
Total costs	\$3,853,457	
Cost per tonne sludge treated[a]	\$68	
Standard aerobic digestion		
Capital	\$813,000	Includes equipment, building, and process tank costs
Operating	\$351,000	Includes chemical and operating costs
Disposal	\$1,020,634	Based on \$11.40/tonne and \$1.80/kg polymer
Energy	\$1,965,061	Based on \$0.07/kWh
Total costs	\$4,149,694	
Cost per tonne sludge treated[a]	\$64	
Mechanical thickening aerobic digestion		
Capital	\$750,000	Includes equipment, building, and process tank costs
Operating	\$702,000	Includes chemical and operating costs
Disposal	\$1,020,634	Based on \$11.40/tonne and \$1.80/kg polymer
Energy	\$1,452,741	Based on \$0.07/kWh
Total costs	\$3,925,375	
Cost per tonne sludge treated[a]	\$60	

[a]Capital costs are amortized over the 15-year life cycle at an interest rate of 5%. Prices in US\$.

tanks and results in reduced energy and concrete costs. Improved digestion performance provides reduced quantities of sludge to be disposed of and as discussed previously lowers operation and maintenance costs. In addition a membrane thickening aerobic digestion process can be retrofitted in existing tanks, which is critical for WWTPs that are limited in space.

This example can help quantify the financial impact of the many advantages a membrane thickening aerobic digestion process can have. Let us consider a WWTP that is considering a new solids handling facility, Plant A. Plant A is considering three Class B solids handling alternatives: a membrane thickening aerobic digestion process, a mechanical thickening aerobic digestion process, and a standard aerobic digestion process utilizing decanting to thicken WAS. Plant A is a municipal WWTP, has a flow of 15,142 m^3 per day, influent BOD concentration of 250 mg/L, and sludge yield of 0.7 kg WAS per kg of BOD. Table 1 shows a cost comparison of the solids handling alternatives over a 15-year life cycle – the typical life of a WWTP is 15 to 20 years.

As seen in the Table 1 and Figure 2, although a membrane thickening aerobic digestion processes has the highest capital cost and cost per tonne of sludge treated than the other two alternatives, it offers the lowest overall life cycle costs. Membrane thickening aerobic digestion processes provide more than a 60% reduction in operating costs when compared with mechanical thickening aerobic digestion. Based on these findings the operator attention costs associated with mechanical thickening equipment is quite substantial, as membrane thickening aerobic digestion requires very minimal operator attention. In addition membrane thickening aerobic digestion has reduced costs in every category with exception of capital costs when compared with standard aerobic digestion. It is widely recognized that equipment associated with membrane processes have very high capital costs in comparison to other technologies, however, as seen in the above example, membrane thickening technology can be a very cost-effective solution when 15- to 20-year life cycles are considered.

Impacts of high-nutrient side streams

High nutrient concentrations in plant recycles or side streams from solids handling processes are widely recognized as a leading cause of high nitrogen and phosphorus in plant effluents of biological nutrient removal (BNR) facilities, therefore the selection of a solids handling process is crucial when designing a WWTP. Critical issues associated with high nutrient recycles from solids handling processes include the inability to comply with nitrogen and phosphorus effluent

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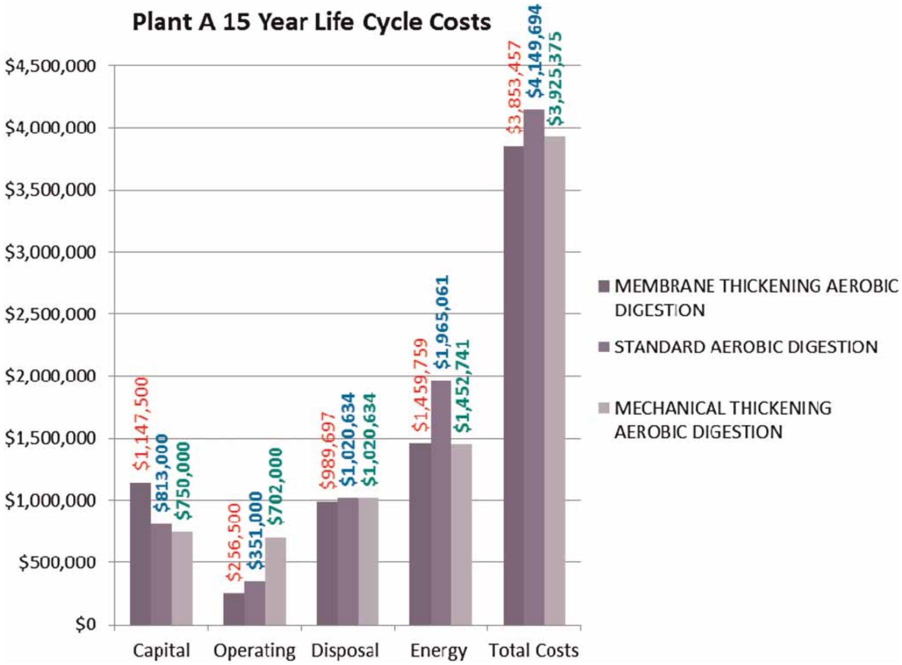

Figure 2 | Chart of Plant A's 15-year life cycle costs.

discharge limits, increased operating costs associated with chemical addition to remove nutrients, and depletion of the carbon to nitrogen ratio in the liquid treatment process, preventing denitrification for complete nitrogen removal.

Solids handling processes such as anaerobic digestion or autothermal thermophilic aerobic digestion (ATAD) are known to generate hundreds or even thousands of mg/L of total nitrogen and phosphorus in side streams recycled to the head of the plant. Side streams from dewatered anaerobic digested sludge can contain 900–1,500 mg/L of ammonia, which can increase ammonia concentration in the plant influent by 3–5 mg/L on an average day. If such a side stream is returned, it can have a profound impact on oxygen uptake and the aeration design system of the liquid treatment process (Bernard *et al.* 2006).

Nitrosomonas and *Nitrobacter* bacteria are temperature sensitive and will die at temperatures exceeding 49 °C. ATAD processes are typically operated at temperatures ranging from 45 to 60 °C, which will inhibit the nitrification process, resulting in increased ammonia accumulation. ATAD systems have similar side stream ammonia concentrations to anaerobic digestion processes, which range from 800 to 1,500 mg/L (Oerke 2010).

Excessive nutrients from biological process side streams can have adverse economic impacts. In order to remove phosphorus and nitrogen from the effluent, a separate side stream treatment process, lime stabilization, and chemical addition of alum, acetic acid, or ferric chloride may be required. These alternatives can add substantial costs and the addition of chemicals or lime can increase sludge loads to 40%, which also increases the associated costs of dewatering and disposal. For example, acetic acid is commonly used as a source of volatile fatty acid (VFA) to enhance biological phosphorus removal (BPR). Charlotte Mecklenburg Utilities (CMU) in North Carolina operates the 45,426 m^3 BPR McDowell Creek WWTP and use acetic acid to enhance phosphorus removal. Since 1999, at a rate of 5.3–7.9 m^3 per day of acetic acid, the McDowell Creek WWTP has spent approximately $400,000 annually (Fiss *et al.* 2010).

In addition, if too much nitrogen from side streams is recycled back to the head of the plant, it can deplete carbon to nitrogen ratios and prevent the denitrification process from achieving complete nitrogen removal in the liquid treatment process. If carbon to nitrogen ratios are depleted, an external carbon source such as methanol or Micro-C™ would need to be added to achieve complete nitrogen removal. There are nearly 200 wastewater treatment facilities in the USA that use methanol as a carbon source to achieve denitrification. Although methanol addition is widely used and is generally economical, it has disadvantages, such as being highly flammable and highly toxic. Methanol addition can be expensive, depending on how much needs to be added. Because most of the methanol used in the USA is imported, prices can fluctuate greatly

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and typically costs range from $5.11 to $12.30 per liter. To remove 1 kg of nitrate approximately 3.5 kg of methanol are required (Fiss *et al.* 2010).

Membrane thickening aerobic digestion process produces reuse-quality permeate

The permeate produced from a membrane thickening aerobic digestion process (see Figure 3) is reuse quality, containing a minimal amount of total nitrogen, total suspended solids, and phosphorus. Recycling the permeate to the head of the plant will protect the effluent quality of the BNR biological process without requiring chemical addition, avoids the addition of supplemental carbon sources or a side stream treatment process. Because the permeate is reuse quality it can also be sent directly to disinfection or combined with the plant effluent.

RESULTS: CASE STUDIES OF MEMBRANE THICKENING AEROBIC DIGESTION PROCESSES

Dundee WWTP, Dundee, Michigan

Dundee, MI WWTP required a process that could provide Class B sludge for subsurface injection which would not negatively impact their BNR activated sludge system. Since subsurface injection timing was limited due to regular heavy snowfall, the facility was required to have a holding time of approximately 180 days with very limited sludge hauling. Compliance showing Class B stabilization is demonstrated through pathogen results. Table 2 shows the pathogen count in CFU per dry gram in the solids prior to subsurface injection. As can be seen in the table, the sludge stabilized by the membrane aerobic digestion system is well below the required pathogen count of 2,000,000 CFU/dry gram for Class B criteria.

Figure 3 | Permeate produced from a membrane thickening aerobic digestion process.

To increase the SRT to 180 days, Arcadis Engineers integrated the membrane thickening aerobic digestion process with existing aerobic digester tanks. Only a new MBT was added to form a complete membrane thickening aerobic digestion process (see Figure 4).

After implementing the membrane thickening aerobic digestion process, the plant was able to thicken from 2.5 to 5.5% solids prior to the season when subsurface injection was not possible, all without the use of polymers. Due to the improved performance, the 180-day storage objective was achieved and the facility was able to limit sludge hauling to twice a year. Direct results from this upgrade allowed the plant to double their capacity to 4,543 m^3, while reducing their sludge disposal costs by nearly 40%.

Table 2 | Dundee WWTP pathogen count of sludge stabilized by membrane thickening aerobic digestion process

Dundee WWTP fecal coliform results Sludge stabilized by membrane thickening aerobic digestion system Date	Geometric mean (CFU/dry gram)	% Solids
21 March 2006	57,270	3.29
19 April 2007	281,552	3.23
13 March 2008	78,125	3.13
18 March 2009	33,434	2.18
10 March 2010	146,602	2.32
1 November 2010	75,157	1.55
14 March 2011	110,940	3.63
14 September 2011	5,547	2.74
28 March 2012	101,430	1.77
9 October 2012	45,792	2.47
14 May 2013	57,859	3.08
Average	**90,337**	**2.67**

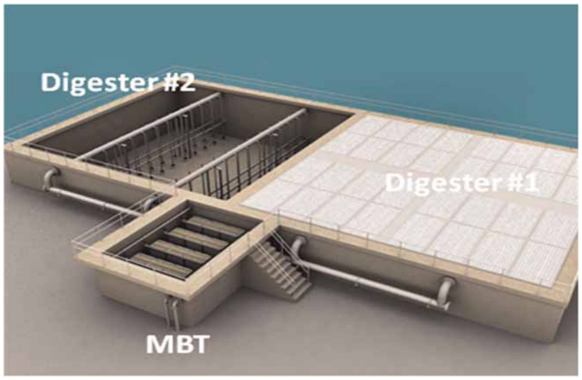

Figure 4 | Dundee, MI WWTP membrane thickening aerobic digestion facility.

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The high-quality permeate from the membrane thickening aerobic digestion process allowed it to be rerouted to the head of the plant without compromising the performance of the BNR activated sludge process. The type of permeate quality shown in Table 3 has been sustainable throughout the entire course of the operation of the Dundee membrane thickening aerobic digestion process.

Union Rome WWTP, Union Rome, Ohio

Since December 2009, Union Rome WWTP in Union Rome, Ohio currently operates an MBR activated sludge system followed by a membrane thickening aerobic digestion process.

CT Consultants were contracted by Union Rome Sewer Authority to design a wastewater treatment facility to handle its municipal wastewater. The main objective of the Union Rome WWTP design was to minimize the footprint of the facility so that all operations could be constructed in one building. Membrane thickening aerobic digestion processes provided the smallest footprint out of all the aerobic digestion options CT Consultants considered, which minimized construction costs of the building.

The Union Rome WWTP membrane thickening aerobic digestion process shown in Figure 5 consists of an MBT operating in-loop with an anoxic and aerobic digester tanks. During digestion, the aerobic zones (the membrane thickener and digester) provide nitrification while the anoxic basin provides built-in time for denitrification and stabilizes the pH. This continuous nitrification and denitrification sequencing eliminates nitrate and ammonia in the permeate which is critical in allowing the facility to comply with their ammonia effluent discharge limit of 1.0 and 0.3 mg/L for summer and winter operations respectively.

Table 3 | Dundee WWTP membrane thickening aerobic digestion permeate results

Parameter	Results (mg/L)
BOD	1.12
Total suspended solids (TSS)	2.00
Total phosphorus	1.09
NH_3-N	0.22
NO_3-N	0.03

Sludge at the Union Rome WWTP is thickened up to 5% solids (average of 4.15% solids), which is consistently more than triple the concentration of the influent total solids wasted from the MBR biological process. The thickening performance of the Union Rome WWTP membrane thickening aerobic digestion process is shown in Figure 6.

Permeate produced from the membrane thickening aerobic digestion process at the Union Rome facility is combined with the MBR effluent which is sent directly to disinfection. As shown in Table 4 the permeate from the membrane thickening aerobic digestion process contains less than 0.1 mg/L of ammonia, which is well below the facility's effluent discharge limit mentioned above.

After the WAS is processed in the membrane thickening aerobic digestion process it is sent directly to a belt filter press for sludge dewatering then disposal to a sanitary landfill. Prior to incorporation of the membrane thickening aerobic digestion system, the Union Rome facility operated their belt press 5 days a week (260 days per year). Improved thickening achieved with the membrane thickening aerobic digestion process as described above substantially increased the capacity of the Union Rome facility, resulting in reduced belt filter press operations and decreasing the frequency of the sludge to be dewatered. The membrane thickening aerobic digestion process reduced the belt filter press operations at the Union Rome WWTP to 3 days every 2.5 months (15 days per year). Since operating the membrane

Figure 5 | Union Rome WWTP membrane thickening aerobic digestion system (MBT shown on the left, aerobic digester shown on the right).

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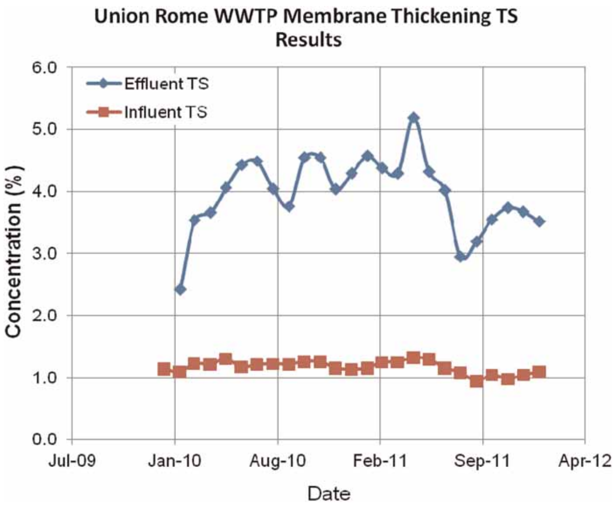

Figure 6 | Union Rome WWTP thickening results of aerobic digestion system.

Table 4 | Union Rome WWTP permeate results (February to January 2012)

Parameter	Result (mg/L)
BOD	<1.0
TSS	<1.0
Total phosphorus	<5.0[a]
NH_3-N	<0.1

[a]No biological phosphorus removal in MBR process upstream.

thickening aerobic digestion process the Union Rome facility has increased their belt press efficiency by using 40% less polymer to dewater the same amount of solids as the previous sludge handling process and reduced the quantity of sludge hauled to landfill by more than 50%. This has resulted in savings of over $58,000 in hauling costs and over $3,000 in polymer costs annually.

CONCLUSIONS

Although membranes are more commonly applied in liquid wastewater treatment and water treatment processes, they can also be utilized in solids handling systems. Membrane thickening processes are controlled aerobic digestion processes that integrate WAS thickening with membranes. Thickening with the membranes provides continuous, automated, and improved thickening that does not require the use of polymers or attention to decanting. Although a membrane thickening aerobic digestion process is considered an unconventional solids handling approach it offers the lowest life cycle costs when compared to more conventional aerobic digestion systems. Membrane thickening aerobic digestion processes are suitable for handling WAS from many biological liquid treatment processes such as MBR and conventional processes, but are ideal for facilities that are obligated to meet strict nutrient discharge limits, specifically total nitrogen and phosphorus. Membrane thickening processes provide outstanding permeate quality with reduced nitrogen and phosphorus, which minimizes side stream nutrient loading to the head of the plant.

REFERENCES

Bernard, J., Kobylinski, E., Phillips, H. & Wallis-Lage, C. 2006 Nitrogen and phosphorus-rich side streams: managing the nutrient merry-go-round. *2006 WEFTEC Proceedings*, pp. 5282–5304.

Bilyk, K., Pitt, P., Taylor, R. & Wankmuller, D. 2011 Process and economic benefits of side stream treatment. *2011 NC AWWA-WEA Conference Proceedings*, pp. 1–11.

Burton, F. & Tchobanoglous, G. 1991 *Wastewater Engineering Treatment, Disposal, and Reuse*. 3rd edn, Metcalf & Eddy, Inc., p. 774.

Fiss, E., Fiss, E. M. & Rebodos, R. 2010 Alternative carbon sources for achieving biological nutrient removal at municipal wastewater treatment plants. *2010 NCWAA Conference Proceedings*, pp. 1–8.

Ju, L.-K., Shah, H. K. & Porteous, J. 2005 Phosphorus Release in Aerobic Sludge Digestion, Red Orbit News. Water Environment Federation.

Oerke, D. 2010 Second generation ATAD – A TAD better? – two case studies of conversion from 'First generation to second generation' ATAD systems. *2010 WEF Residuals and Biosolids Conference Proceedings*, pp. 1–14.

US Environmental Protection Agency 1993 *Title 40 – Protection of the Environment Code of Federal Regulations (CFR) Part 503 'Standards for the Use or Disposal of Sewage Sludge'*. EPA-831-B-93-002b, Office of Enforcement and Compliance Assurance, Washington, DC.

US Environmental Protection Agency 1999 *Biosolids Generation, Use, and Disposal in the United States*. EPA-832-F-00-503, Office of Water, Washington, DC.

US Environmental Protection Agency 2006 *Emerging Technologies for Biosolids Management*. EPA-832-R-06-005, Office of Wastewater Management, Washington, DC.

Van Haandel, A. & Van der Lubbe, J. 2007 Wastewater treatment design and optimization of activated sludge systems. *Model of Biological Phosphorus Removal* **5.1.3**., 197–198.

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