DIGESTIVORE™: KILLING FOUR BIRDS WITH ONE STONE

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ABSTRACT

A side stream is any process flow resulting from the treatment of biosolids that flows back to the liquid treatment process. Examples of side streams are filtrate or centrate from dewatering operations and supernatant from digestion processes. If a plant recycles very high concentrations of ammonia from side streams, it can be difficult to remove the excess ammonia in the mainstream liquid treatment process making it problematic to comply with effluent discharge limit permit requirements. In fact side stream flows are approximately 1% of the total influent hydraulic plant flow but consequently account for 15% to 40% of the influent total nitrogen load (Pugh and Stinson, 2012). Side stream flows that range from 900 to 1,500 mg/L as nitrogen (N) or more can increase the ammonia concentration in the plant effluent by 3 to 5 mg/L on an average day basis (Phillips, Kobylinski, Barnard, Wallis-Lange, 2006).

In addition, side stream flows with excessive ammonia concentrations can create operational issues to liquid treatment process operations, especially to those whose goal is to achieve total nitrogen removal. Excessive ammonia concentration in side streams can cause depletion of carbon to nitrogen ratios since ammonia generally accounts for 60% of the Total Kejldahl Nitrogen (TKN). Reduced carbon to nitrogen ratios can make the denitrification process problematic to achieve. To achieve denitrification when the carbon to nitrogen ratio is depleted in the liquid treatment process adding an external carbon source such as methanol or Micro-C™ may be necessary, which results in increased sludge loads and operating cost.

To improve wastewater treatment plant operations and reduce operating cost associated with the addition of chemicals and disposal costs, treatment of side stream flows can be very advantageous. Side stream treatment can theoretically remove about 85% of ammonia, thereby reducing the load that is returned to the head of the plant. Removing ammonia in side streams requires less volume and lower construction costs than if it were treated in the mainstream liquid treatment process. This is due to the concentrated load and higher temperature which leads to faster kinetics in the side stream. Typically side stream treatment management for ammonia is commonly conducted with biological and physical-chemical processes. Notable sustainable biological side stream management processes include nitrification/denitrification, bio-augmentation, nitritatation and denitritation, and deammonification (ANAMMOX). Typical physical-chemical processes used for side stream management include ammonia stripping (steam, hot air, and vacuum distillation), ion exchange (Ammonia Recovery Process (ARP)), and struvite precipitation (Magnesium Ammonia Phosphate (MAP)). Side stream treatment for ammonia utilizing a biological process while integrating waste activated (WAS) thickening with a membrane unit is a new concept.

This paper describes the Digestivore™ process, a new development in side stream treatment technology. This process functions as a sludge handling system and also provides biological ammonia treatment of side streams. The Digestivore™ process is a very versatile and robust technology that features an aerobic digestion process utilizing flat plate membranes for thickening waste activated sludge (WAS) and biological treatment of dewatering side streams from solids handling processes that produce high concentrations of ammonia, most notably anaerobic digestion and autothermal thermophilic aerobic digestion (ATAD) systems. This system is suitable for facilities with anaerobic digestion or ATAD systems that must comply with effluent discharge permit limits for ammonia, that have odor problems, and are looking to increase biological capacity but are limited in footprint.

KEYWORDS

Membrane, Thickening, Ammonia Side Stream Treatment, Biological Treatment, Solids Handling, Sludge

INTRODUCTION

Discharge of wastewater containing excessive amounts of ammonia into lakes, reservoirs, rivers, and streams is toxic to plant and animal life and depletes dissolved oxygen in water. Toxicity to fish in freshwater has been observed at low concentrations of 0.068 to 2.0 mg/L of ammonia, depending on species, temperature, and pH. At much lower concentrations, aquatic life become less active affecting migration, feeding, and reproduction (Parker, 2012). In fact it was found that the growth rate of mussels in the St Croix River was substantially reduced at ammonia concentrations as low as 31 µg/L of ammonia (Newton, 2002). Due to concerns with ammonia toxicity to aquatic life, many wastewater treatment facilities in the US and Canada are required to nitrify their effluent in order to avoid ammonia toxicity in receiving waters. Therefore, they are required to comply with effluent discharge permit limits for ammonia.

Although side stream flow at a wastewater treatment facility represents a very small portion of the overall plant flow, it can largely impact effluent quality for ammonia. Processes that are well known to have ammonia rich side streams are anaerobic digestion and ATAD processes. Ammonia rich side streams as from an ATAD process can be treated through the nitrification which is driven by nitrifying bacteria species Nitrosomonas and Nitrobacter which use oxygen to oxidize ammonia into nitrate. 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°C to 60°C. These temperatures will inhibit the nitrification process. Therefore significant ammonia concentrations ranging from 800 to 1,500 mg/L can be recycled in the centrate/filtrate from this process (Oerke, 2010).

For an anaerobic digestion process, there is not an aerobic zone for microorganisms to facilitate the oxidation of ammonia into nitrate. Therefore, ammonia concentrations in dewatering side streams from anaerobic digestion processes can range from 900 to 1,500 mg/L as nitrogen (N) or more. This can increase the ammonia concentration in the plant effluent by 3 to 5 mg/L on an average day basis. That is, if such a side stream is returned, it can have a profound impact on oxygen uptake and aeration design of the mainstream liquid treatment process (Phillips, Kobylinski, Barnard, Wallis-Lange, 2006). Based on these findings side stream management of ammonia is very critical in order to meet effluent discharge permit limits for ammonia.

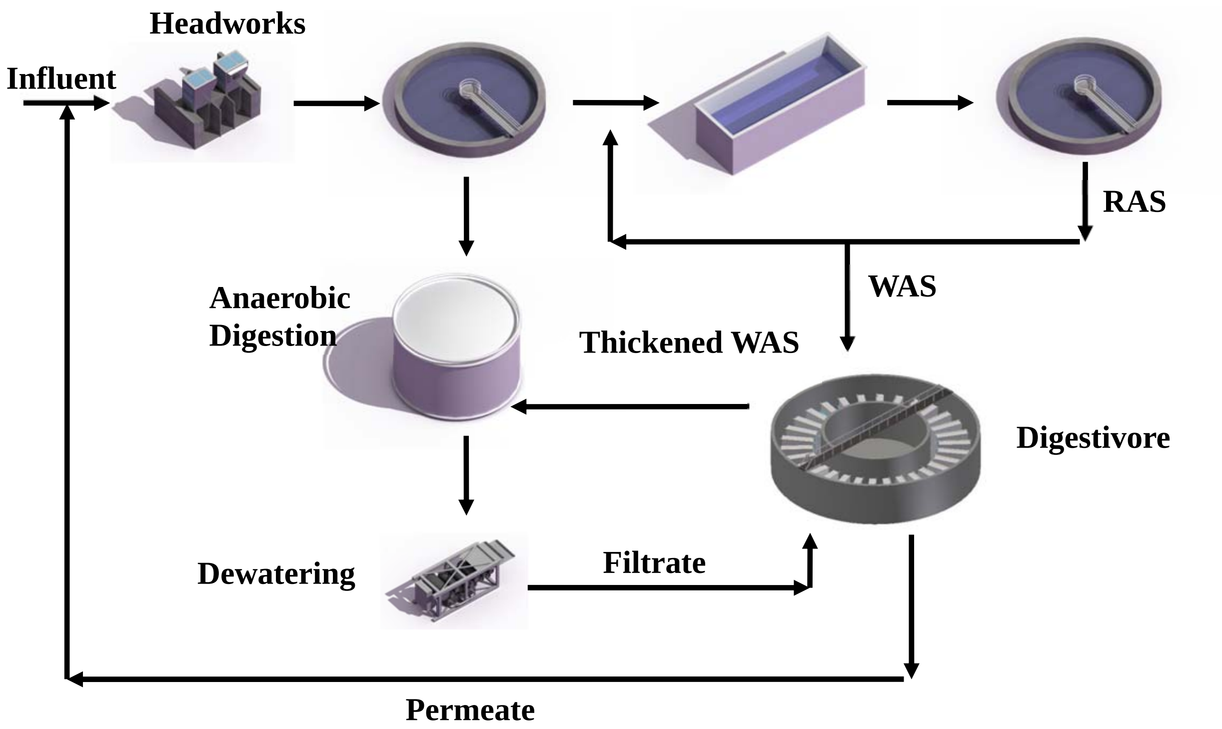
METHODOLOGY: SIDE STREAM AMMONIA TREATMENT

Sending side stream flow to the head works of the plant or directly to the mainstream liquid treatment process is a common practice at wastewater treatment facilities, however this may have some consequences. Treating additional ammonia load from a side stream in a liquid treatment process can increase capital and operating costs, because it requires additional volume and energy for aeration required for biological oxidation of ammonia into nitrate. Utilizing side stream treatment can theoretically remove about 85% of ammonia, thereby reducing the load that is returned to the head of the plant. Removing ammonia in side streams requires less volume and costs less than if it were treated in the mainstream liquid treatment process due to the concentrated load and higher temperature which leads to faster kinetics in the side stream.

Bilyk, Taylor, Pitt, and Wankmuller (2011) examined a case study from a wastewater treatment plant (Plant A) that is considering side stream treatment and compared the economic impact of this facility having side stream treatment and without it. They observed that side stream treatment of Plant A with 19% of its influent nitrogen load from the side stream would defer the need for new process tanks by 10 years. This had a net present cost savings (20 years, 5% costs of financing, 3% cost of inflation) of $6.6 million. In addition they compared operating costs for Plant A. They found it would cost $0.93 per pound of total nitrogen removed using side stream treatment versus $2.66 per pound of nitrogen removed without side stream treatment, i.e. nitrogen removal in the mainstream liquid process.

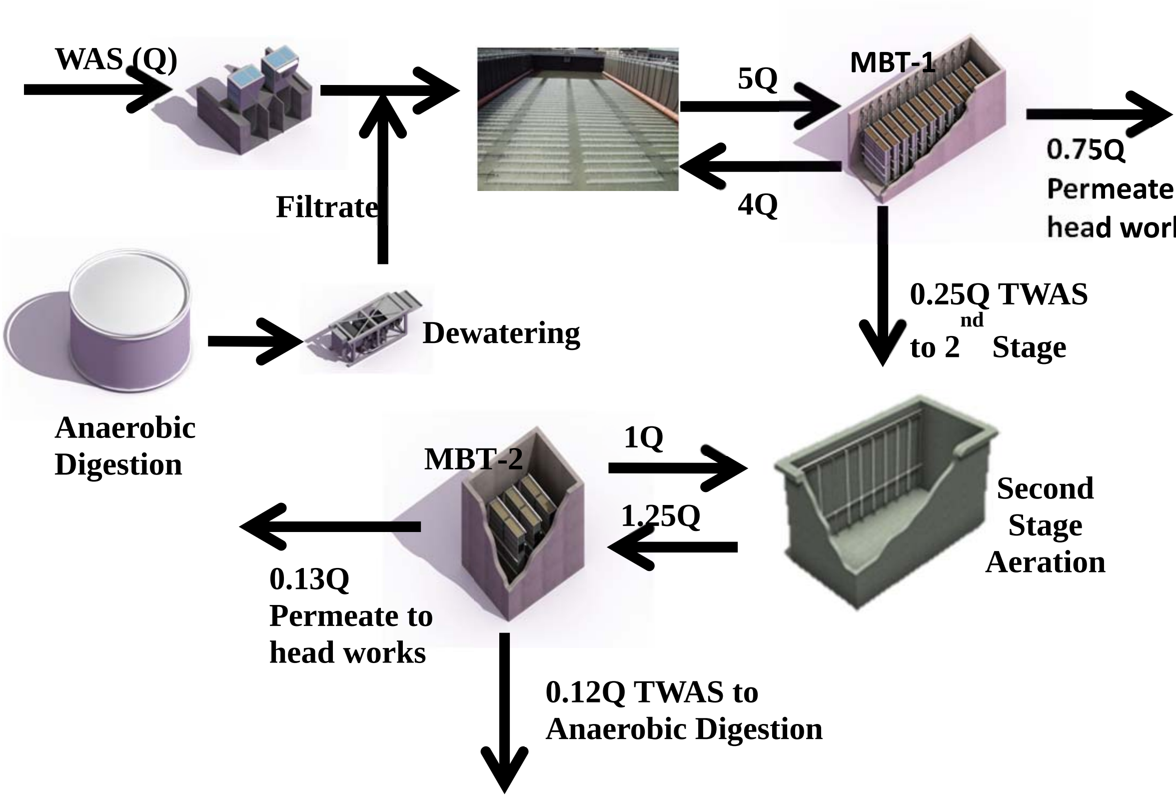
Common side stream ammonia treatment is conducted through biological and physical-chemical processes. The Digestivore™ process is a new development that functions as a sludge handling system and also provides biological ammonia treatment of side streams The Digestivore™ process is a very versatile and robust technology that features an aeration process utilizing flat plate membranes for thickening waste activated sludge (WAS). It also enables biological treatment of dewatered side streams from solids handling processes that produce high concentrations of ammonia, most notably anaerobic digestion and ATAD systems. Figure 1 below shows a typical wastewater treatment plant that integrates a Digestivore™ process.

Figure 1: Typical Wastewater Treatment Plant with a Digestivore™ Process



The Digestivore™ is a dual stage membrane thickening process that typically consists of first and second stage membrane thickening and aeration tanks. The centrate/filtrate from the dewatering operations that contain the high ammonia concentrations and WAS is sent directly to the first stage aeration tank where it is aerated with a high efficiency fine bubble diffuser system. The WAS provides a healthy population of nitrifying bacteria, and under intense aeration in the first stage aeration tank, is capable of removing the majority of ammonia in the side stream. The WAS in the first stage aeration basin is then recycled to the first stage membrane thickening tank where it is thickened up to 2% solids, and the wastewater filtered out of the membranes (permeate) is sent to the head works of the plant. When the maximum liquid level in the first stage membrane thickening tank is reached, a portion of the WAS is sent to a second stage aeration tank. Here, it is aerated with coarse bubble diffusers in order to remove the remaining ammonia in the process. When full, a portion of the WAS in the second stage aeration tank is then sent to the second stage membrane thickener tank. Here, it is thickened up to 4% solids while permeate is recycled to the head of the plant. When the second stage membrane thickening tank is full, a small portion of the WAS in this tank is transferred to the anaerobic digestion or ATAD process. Figure 2 below shows a typical Digestivore™ process flow diagram.

Figure 2: General Digestivore™ Process Flow Diagram



The primary advantages to using the Digestivore™ process are as follows: 1) the ammonia in the dewatering side streams is removed biologically without the use of chemicals; 2) it can be retrofitted into almost any existing tanks; 3) the construction of the buildings is not required for membrane thickening equipment; 4) it increases biological capacity within the aeration basins; and 5) it provides odor control. In addition, the improved thickening of the WAS with membranes allows for better performance of the anaerobic digestion or ATAD processes.

The Digestivore™ process also features lower operating costs due to more reliable thickening of WAS with membranes. This reduces operator involvement, because it is done without the use of polymers or attention associated with the use of mechanical equipment such as shutdown, startup, and clean up time.

DISCUSSION AND RESULTS: EVALUATING THE DIGESTIVORE PILOT SYSTEM AT FOX LAKE, ILLINOIS WWTP

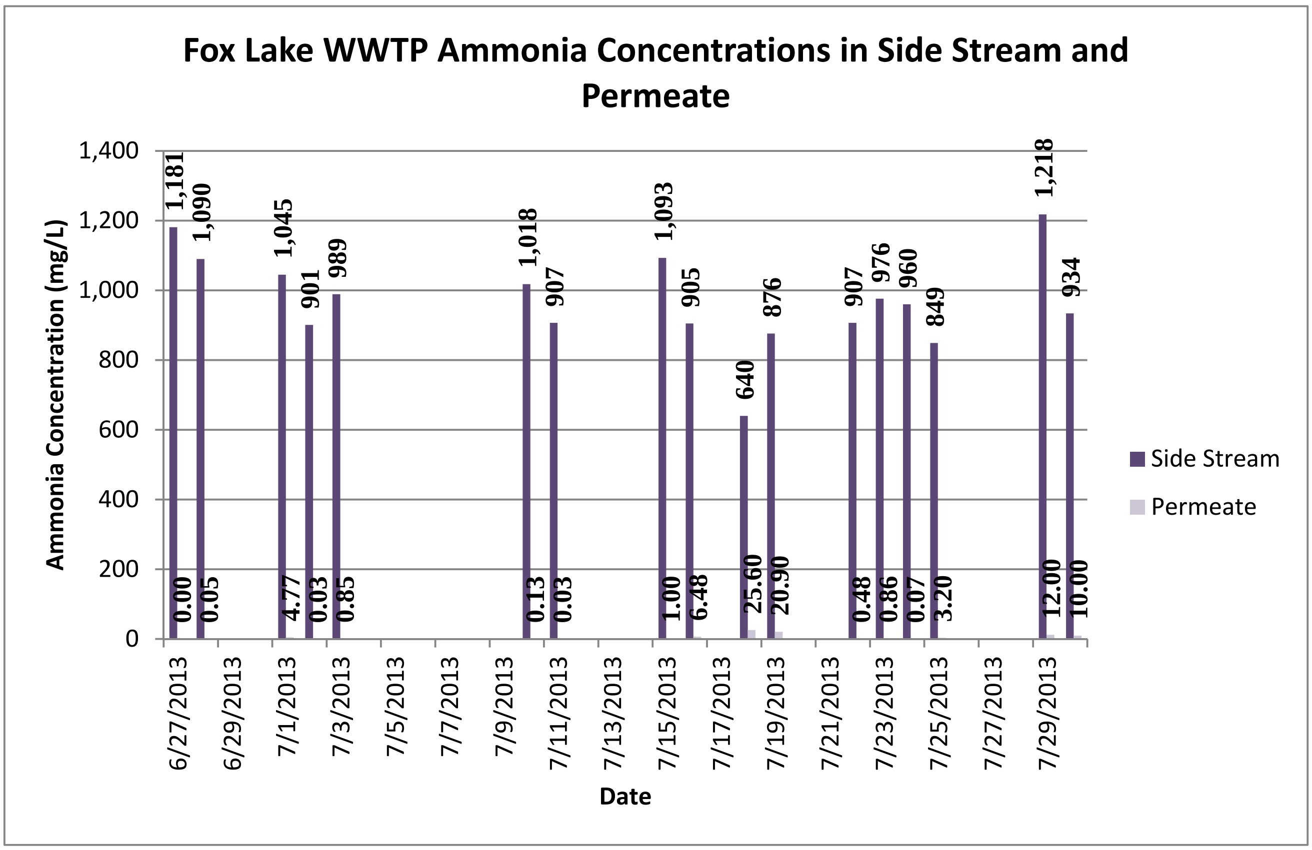
Since the Digestivore™ is a new concept and an unproven technology, a pilot study was conducted at the Fox Lake WWTP in Fox Lake, Illinois from June 2013 to July 2013 to evaluate ammonia removal capabilities in side stream flow. The primary components of the Digestivore™ Pilot System consists of the following: first and second stage membrane thickening (MBT) basins each containing a flat plate submerged membrane unit (SMU) to thicken WAS; first and second stage aeration basins; high efficiency fine bubble diffusers in the first stage aeration basin; coarse bubble diffusers in the second stage aeration basin; regenerative blowers to provide scouring air to both MBT basins and process air for the aeration basins; and progressive cavity pumps to extract permeate from both MBT basins. The Digestivore™ Pilot System that was used to conduct the testing is shown in Figure 3 below.

Figure 3: Digestivore™ Pilot System

The Fox Lake WWTP is a 9 MGD facility with a conventional activated sludge liquid treatment process, anaerobic digestion solids handling process, and a belt filter press for dewatering that sends the filtrate to the head works of the plant. The facility must comply with a national pollutant discharge elimination system (NPDES) permit effluent limit for ammonia of 0.8 mg/L based on a monthly average and a 2.2 mg/L daily average. To evaluate the effectiveness of biological side stream ammonia treatment at this facility, the filtrate from the belt filter press was sent directly to the Digestivore™ Pilot System instead of the head works of the plant. The WAS from the conventional activated sludge system was also sent to the Digestivore™ Pilot System and thickened in the first and second stage MBT basins. The first stage aeration basin used high efficiency fine bubble diffusers to aerate the thickened WAS with filtrate while the second stage aeration basin utilized coarse bubble aeration. From June 27, 2013 to July 29, 2014, samples from both the filtrate from the belt filter press and the Digestivore™ Pilot System MBT basin permeate were collected and analyzed for ammonia, nitrate, total nitrogen, and total phosphorus at the plant laboratory. Samples of the influent WAS and Digestivore™ thickened WAS were collected and analyzed for total suspended solids.

The average TSS of the WAS from the conventional activated sludge liquid treatment process was approximately 7,000 mg/L. The Digestivore™ Pilot System thickened the WAS to an average TSS of 14,000 mg/L in the first stage MBT basin and up to 35,000 mg/L in the second stage MBT basin. The side stream at the Fox Lake facility entered the Digestivore™ Pilot System at an average of approximately 460 gallons per day and contained an average of 970 mg/L (maximum 1,218 mg/L) of ammonia, 1.39 mg/L (maximum 1.72 mg/L) of nitrate, 2,140 mg/L (maximum of 4,100 mg/L) of total nitrogen, and 20.4 mg/L (maximum 63.3 mg/L) of total phosphorus. The permeate extracted from the pilot unit contained ammonia ranging from 0 mg/L to 26 mg/L, phosphorus ranging from 0 mg/L to 4.18 mg/L, total nitrogen ranging from 29 mg/L to 74 mg/L, and nitrates ranging from 15 mg/L to 116 mg/L. Although theoretically side stream treatment can remove up to 85% of the ammonia, the Digestivore™ Pilot System was capable of side stream ammonia removal of 96% to 99%. These results are highlighted in Figure 4 below.

Figure 4: Comparison of Ammonia Concentrations between Side Stream Flow and Permeate from Digestivore™ Pilot System



Even though the primary objective of the Digestivore™ system is to provide biological side stream ammonia, it also provided total phosphorus removal of more than 99% during the entire duration of the testing. The Digestivore™ Pilot System permeate contained higher nitrate concentratons than the influent side stream flow, however it had a much lower total nitrogen cocentration. The reason for this is the Digestivore™ Pilot System removed almost all the ammonia in the side stream. The amount of nitrate generated by the Digestivore™ system is very small in comparison to the ammonia that was removed. This resulted in reduced total nitrogen from the Digestivore™ Pilot System permeate in comparison with the in fluent side stream flow that had high ammonia and low nitrate concentrations.

CONCLUSIONS

Excessive discharge of ammonia into water bodies can have negative impacts on the environment, because it can be toxic to aquatic life and can result in the depletion of dissolved oxygen levels in water. Due to concerns with excessive ammonia discharge, many wastewater treatment plants are obligated to meet NPDES effluent discharge limits for ammonia. If a wastewater treatment plant recycles too much ammonia in side streams produced from biosolids handling processes, it can be very difficult to meet NPDES effluent discharge limits for ammonia. Therefore, it is very important to consider side stream management processes when designing a wastewater treatment plant.

The Digestivore™ process offers biological side stream ammonia treatment utilizing membrane thickening of waste activated sludge. The Digestivore™ process is a very versatile process, because not only does it feature biological ammonia side stream treatment but also provides odor control, increased biological capacity, and reliable thickening of WAS to improve performance of anaerobic digestion and ATAD systems. This process features many economic benefits such as reduced capital costs due to ammonia removal in a smaller footprint and can be retrofitted into existing tanks. The Digestivore™ process also provides lower operating costs, because thickening is done without polymers or use of mechanical equipment, and the system requires minimal operator supervision.

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