AS GOOD AS THE HYPE: AN OVERVIEW OF THE SECOND GENERATION ATAD PERFORMANCE

JIM SCISSON
4617 ELMHURST RD
TOLEDO OHIO 43613
JSCISSON@AOL.COM
419-474-7697

ABSTRACT

The Thermal Process "second-generation" ATAD system had its first municipal installation in 2002. Since that time there are at least 6 other installations that are operational, and have produced enough data for an evaluation. Previous studies (Scisson 2004 and 2006) have shown good to exceptional solids reduction and dewaterability. This paper examines operating data from 8 installations. This paper also will discuss the evolution of some process improvements such as foam control, the simultaneous nitrification-denitrification reactor (SNDR), passive SNDR cooling, eliminating the need for draw and fill operation for Class A pathogen reduction and the reduction of dewatering costs.

The paper will discuss also some of the "on the fly" adjustments made to the design or operation of the existing reactors

KEY WORDS ATAD, SNDR

INTRODUCTION

The Thermal Process "2nd Generation" ATAD has been in municipal service since 2002. Previous reports on their performance have been published for ATAD reactors at Three Rivers, MI and Bowling Green, OH. At this time (2009) there are 7 municipal installations with 2-6 years operating experience. The ATAD design has evolved during this time, especially in regard to foam control, reactor covers and thermophilic/mesophilic staged operation. This paper will provide an overview of 8 installations, including the original installation at the Staley Starch plant in Lafayette, IN.

The ATAD concept is not new, having originated in the 1970's as a pure oxygen autothermal digester. There are one or two pure oxygen ATADs remaining as the first stage of a dual digestion process. There also are approximately 30 other ATAD installations in North America, mostly designs based on designs provided by Fuchs and a pumped venturi mixing system designed by Dayton & Knight Consulting Engineers. These designs suffer from poor performance, tremendous odor problems and high dewatering costs. The "second generation ATAD has addressed the deficiencies of earlier designs and provides a stable reliable and economical method to produce exceptional quality biosolids. Differences between 2nd generation ATAD and previous iterations of the ATAD are:

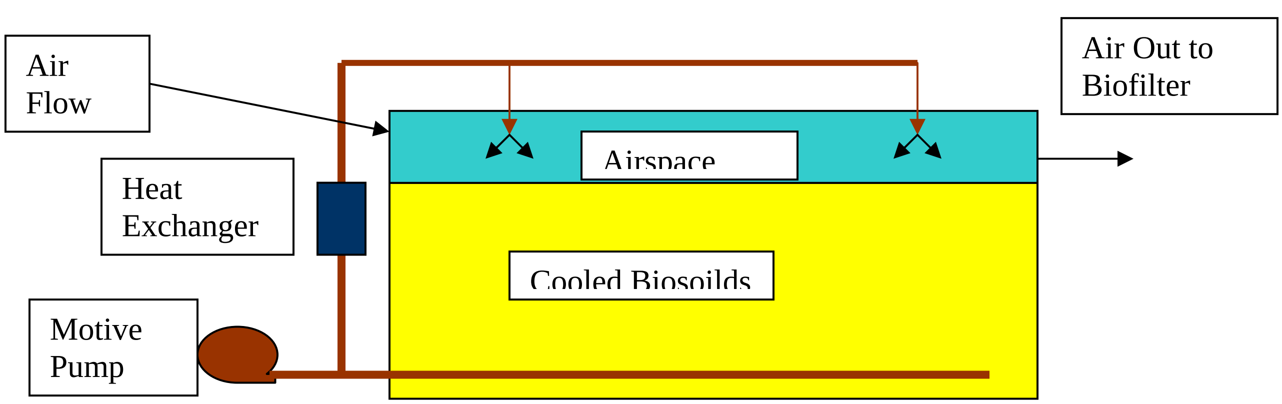
- The Thermal Process ATAD has a thermophilic SRT of 10-14 days, single stage, instead of shorter detention times (2-4 days) with 2 or three stages (6-12 days total)
- Use of pressurized (blower) air for aeration instead of aspirated air or pure oxygen.
- Sufficient aeration pressure to minimize anaerobic conditions and odor production
- Aeration control based on oxidation reduction potential (ORP)
- Non-mechanical foam control
- A mesophilic aeration stage of 8-10 days following the thermophilic stage. The mesophilic stage provides an addition 10-15% solids reduction, is part of the odor control system, and improves the ATAD biosolids dewatering characteristics. This mesophilic stage is called a Simultaneous Nitrification/Denitrification Reactor (SNDR). This innovation is the key to improved performance.

What is an SNDR?

The SNDR provides additional reactor volume at mesophilic temperatures. Figure 1 shows a schematic of a typical SNDR. In the original SNDR a sidestream of the reactor contents is cooled by a cold water to biosolids heat exchanger. The cooled biosolids are sprayed down into the tank headspace, losing heat and dissolving ammonia from the air in the headspace back to the tank liquid contents.

The SNDR can act as part of the odor control system if the off gas from the ATAD reactor is piped to the SNDR headspace. The off gas can have an ammonia concentration in excess of 900 ppmv. The cooled biosolids from the sprayer provide up to a 50% reduction in ammonia and humidify the off gas for further treatment in the biofilter.

Figure 1
SNDR



The SNDR provides additional detention time, which improves solids reduction, and improves the chemistry of the biosolids for dewatering. There will be some discussion of this at the end of the paper.

ATAD Site Overviews

The 8 plants studied include one industrial plant and 7 municipal plants. The municipal plants range in size from 2.5 MGD to approximately 12 MGD. Six of the municipal plants are conventional activated sludge, one is a membrane bioreactor (MBR) and one is an Actiflo/Biostyr plant, or, ballasted flocculation followed by a biological aerated filter. Table 1 shows the capacity of each plant, the year installed, what the ATAD replaced and whether or not it was a retrofit

Table 1
ATAD Plant Characteristics

Plant	Capacity Dry TPD	Date In Service	Process Replaced	New Or Retrofit	Liquid Or Cake Storage/Re Use	Type Of Solids Processed
Staley, Lafayette IN	15	1995	None	New	Cake	TWAS
Three Rivers MI	4	2002	Anaerobic Digestion	Retrofit	Cake	Primary + TWAS + septage
Yorkville IL	2	2004	Aerobic Digestion	New	Cake	TWAS
Bowling Green OH	8	2005	Aerobic Digestion	Retrofit plus New Tanks	Liquid storage plus dewatering	Cosettled Primary + WAS + septage
Morehead KY	3	2005	Anaerobic Digestion	New	Cake	Cosettled Primary + WAS
Delphos OH	4.5	2006	Anaerobic Digestion	New	Cake	TWAS
Heart of the Valley, WI	11	2007	Anaerobic Digestion	Retrofit	Liquid storage	Cosettled Primary + WAS
Marshall MN	6	2006	Anaerobic Digestion	Retrofit	Liquid storage	Cosettled Primary + WAS

Staley Starch, Lafayette, Indiana (15 TPD). The Staley plant is the site of the first "second generation" ATAD system. The Staley Company uses activated sludge to treat waste from the starch plant. Undigested waste activated sludge (WAS) was previously dewatered to 12% solids, trucked to a lagoon, reliquefied, and land applied. The dewatering operation ran 24 hrs/day, 7-days/ wk. There were numerous odor complaints near the land application sites. Staley commissioned the founders of Thermal Process Co. to design something to solve their problem. .

Innovations: As this is the original installation, it can be said that everythingon the project is an innovation. Technology unique to this installation includes:

- Fiberglass covers
- Sonic horns for foam control
- Off-gas diverted to the aeration basin

Problems

- It was difficult to seal the fiberglass covers and heat loss is a problem in cold weather
- The sonic horns used for foam control can crumble the concrete

Results

After the ATAD system was put on-line the dewatering operation schedule was reduced from over 160 hrs/wk to 24 hours/wk, the cake solids improved from 12% to 18%, and the biosolids cake was trucked to a composting operation and mixed with horse stall waste and sold as compost.

Three Rivers, Michigan (4 TPD). Three Rivers, MI is the first municipal "second generation" ATAD. This ATAD system was installed to replace the failing anaerobic digesters and to reduce odor complaints. The ATAD was constructed in the existing biosolids storage tanks, and an existing garage. The ATAD processes primary sludge, thickened waste activated sludge and septage .

Innovations. Innovations at Three Rivers MI included:

- First municipal installation (Figure 1)
- Treats primary solids, TWAS and septage
- Foam control by Foam-Cone^{TM} . Surface foam is sucked into a cone and directed to the suction of a high-pressure pump, that pumps the foam back to the ATAD at high velocity, that entrains the foam into the liquid and beats down the foam layer as well.
- First dedicated storage and cool-down tank.
- First Thermal Process biofilter (figure 3). The biofilter consists of a separate humidification chamber and a biofilter. The biofilter is installed in a concrete

tank with a plenum to distribute the air and a media of coarsely shredded tree roots.

- The processing of primary sludge thickened WAS and screened septage.
- “Triple Redundancy” Following the ATAD system with a dryer so Exceptional Quality Biosolids will be produced even with a treatment process out of service.

Figure 2
Three Rivers ATAD Equipment Room

Figure 3
Biofilter With Humidification Chamber

Problems:

- The former storage tank used as a cool-down/storage tank could not be taken out of service before construction. Draining the tank revealed large cracks that were repaired by epoxy injection.
- The feed solids content was lower than the assumed design, that increased the time required to achieve Class A time and temperature requirements
- The electrical equipment is in the same room as the jet motive and foam pumps. The foam control pump sprung a leak and soaked a variable frequency drive, rendering the VFD inoperable for a time.
- The PLC algorithm that controlled solids wasting from the ATAD reactor to the storage tank was unnecessarily complex. The program would hiccup and waste an excessive volume of hot ATAD biosolids, making temperature and process control difficult. Some real world adjustment was required.
- The storage tank was intermittently thermophilic. Thermophilic conditions caused higher polymer doses.
- The municipal water used in the biofilter humidification chamber is fairly hard (350 ppm). The calcium precipitated out of solution in the humidification chamber and caused stalactites to grow in the chamber, fouling the spray bar. Ferric Chloride was added to the humidification water to prevent precipitation.

Results

Over the first 3 years operation the Three Rivers ATAD produced 45% total solids (TS) reduction, 55% volatile solids (VS) reduction at feed solids flows in excess of design, and feed solids that were significantly below the assumed design concentration. Centrifuge cake solids are 25% concentration. The cake solids are given away to a local farmer.

Figure 4
Design vs. Actual Feed Solids

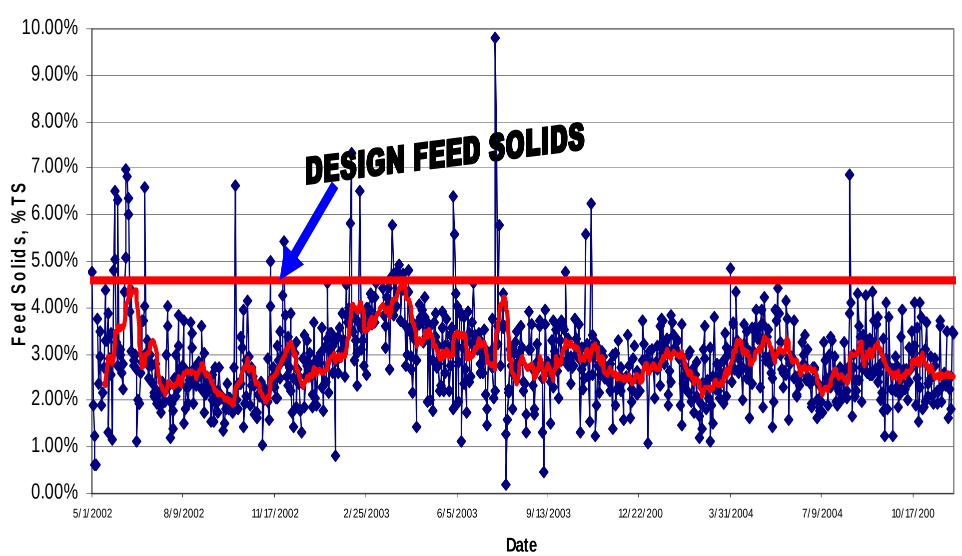
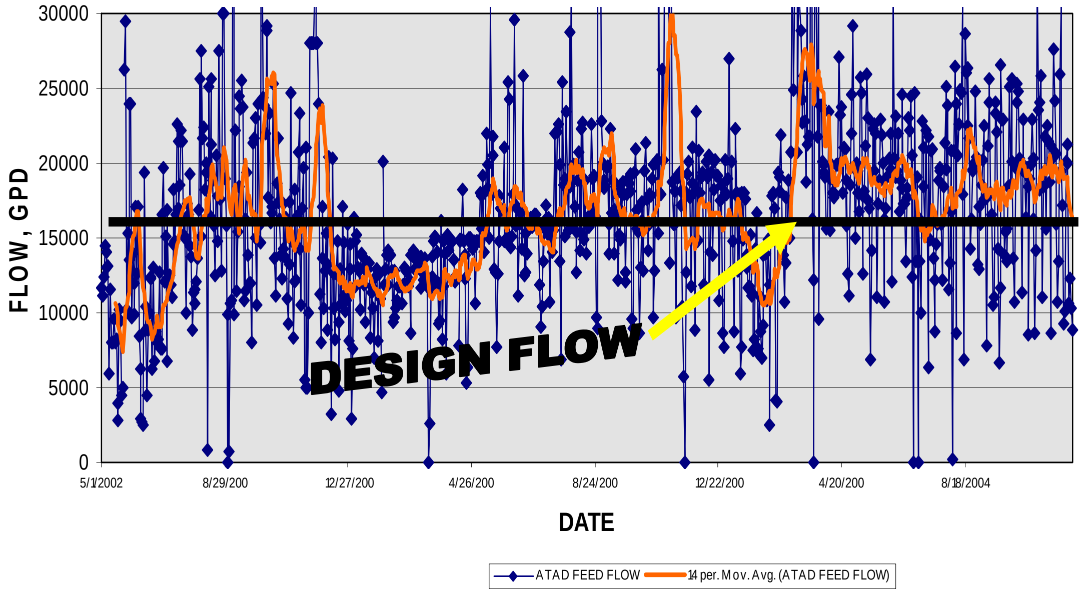


Figure 5
Design vs. Actual Biosolids Feed Flow



Yorkville, Illinois (2 TPD). Yorkville was the second municipal ATAD installation. Selection of the ATAD system by Yorkville was driven not by the need for Class A biosolids, but for biosolids volume reduction and a compact design. The Yorkville WWTP was expanded from 1 MGD to 3.6 MGD on a small site. The plant was using aerobic digestion for biosolids stabilization. The digested biosolids were centrifuged to about 16% TS concentration and then landfilled. The ATAD system was installed because it could digest gravity-belt thickened biosolids in a relatively small volume.

Yorkville was the first site to have a simultaneous nitrification-denitrification reactor (SNDR) In the SNDR the hot (up to 160 F) ATAD biosolids are cooled to 95 F and operated in a nitrification/denitrification mode. The SNDR provides additional solids reduction and improves biosolids dewaterability.
Innovations

- Splashcones^{TM} for foam control (Figure 6). The Splashcone is a cone suspended from the ATAD roof. Biosolids are recirculated from the ATAD reactor and piped to the splashcones. The cone disperses the biosolids around it, and the biosolids "beat down" the foam layer, controlling foam depth.
- First simultaneous nitrification-denitrification reactor (SNDR), where the contents of the cool-down tank are cooled by a heat exchanger (Figure 7)
-
- Cast in place concrete covers with pillars for support.

Figure 6
Splashcones For Foam Control

Figure 7
Yorkville IL Cold Water/Biosolids SNDR Heat Exchanger

Problems

- Higher polymer and coagulant (alum) doses until heat exchanger installed to convert the “cool-down tank” to a SNDR.

Results

At Yorkville, dewatered cake solids increased from 22% to 28-30% concentration, and the polymer dose decreased by 50%. The TS reduction improved from essentially 0% with aerobic digestion to 50% TS reduction with the ATAD. The Yorkville biosolids cake has been certified as compost by a compost-testing laboratory.

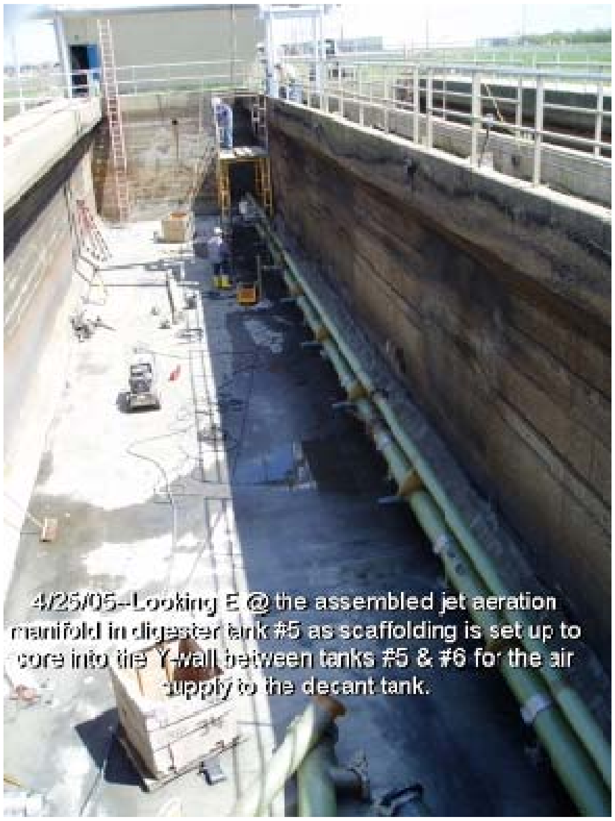
Bowling Green Ohio (8 TPD).

The Bowling Green WWTP is a 10 MGD primary/advanced secondary treatment plant. Before the ATAD system installation primary and secondary solids were aerobically digested and land applied as class B biosolids on city-owned farmland less than 2 miles from the plant. Biosolids were dewatered biosolids when the digesters were full and biosolids could not be applied. The existing aerobic digesters did not perform well (29% TS reduction), created odors and foaming(especially in the spring after the biomass had been in stasis during the winter), and during cold weather ice rafts formed on the surface. Two new ATAD reactors were built, and the four 350,000 gallon existing digesters were converted into a nitrification/denitrification reactor and liquid storage. The nitrification/denitirfication reactor and the storage tanks use jet aeration like the ATAD reactors.

Innovations

- First continuously fed ATAD. Bowling Green has 2 ATAD reactors fed continuously on alternate days. This design eliminated the need for batch feeding and simplified operation
- First plant to treat co-settled primary and secondary biosolids
- First system with open-topped liquid storage of stabilized biosolids (Figure 8)
- First passive heat exchanger (a sludge to air radiator)
- First plant to supernate
- Use of powdered Bentonite as a coagulant
- First use of a shared air supply with the aeration tanks.
- First liquid land application (now abandoned)
- Removable aluminum covers on a portion of the ATAD reactors to allow removal for easier cleaning

Figure 8
Liquid Aeration/Storage Tank



Problems

- Aluminum covers caused excessive heat loss during cold weather.
- The aluminum covers failed the infiltration test. The solution was to seal the covers, making them harder to take apart for cleaning. (Figure 9)
- The non-potable water (NPW) used to cool the SNDR is plant effluent that is not disinfected. The NPW allowed iron-loving bacteria to colonize the ductile iron heat exchanger, fouling and pitting the heat exchanger. The fouled heat exchanger did not cool the SNDR tank, and the temperature rose above the target of 95 F. Nitrification ceased at a tank temperature of 109 F. The heat exchanger was replaced with one made from stainless steel and the tank was again functional.
- The passive heat exchanger was not protected initially from the sun, and served as a biosolids heater instead of a biosolids cooler on sunny days. A sunshade was installed to correct the problem (Figure 10)
- Grit accumulation in the ATAD reactors required that each reactor be taken out of service and the grit removed. Grit removal was also a problem with the aerobic

digesters. The aerobic digesters accumulated grit deposits of approximately 3 feet every 4 years, It was thought that the jet aeration in the ATAD reactors would keep the grit suspended and cleaning would not be required. After needing to be cleaned within the first year of operation, the reactors have now run for 4 years without being cleaned. .

- There were 2 “foam-over” events caused by manual operation of transfer pumps. One foam-over reached the “waters of the State” and caused a small tempest with the Ohio Environmental Protection Agency.
- There are, at times, difficulties obtaining sufficient air to the ATAD reactors from the common aeration supply. The cause of this is unknown at this time. The primary blower, a high-efficiency single vane centrifugal blower, has sufficient capacity and pressure according to design assumptions. Part of the problem may be the low air flow (approximately 2,000 SCFM) and long pipe run (almost 900 feet) from the central blower building to the ATAD reactors.

Figure 9
Infiltration Testing

Figure 10
Passive Radiator with Sun Screen

Results

In 2005, the ATAD system produced total solids reductions of 65% and volatile solids reduction of 72% by mass balance. In 2008 the ATAD produced 61% TS reduction and 72% VS reduction showing consistent, long-term performance.

The ATAD system has a much reduced power demand compared to the previous aerobic digester system. With aerobic digestion and coarse-bubble diffusers, digestion required approximately 15,000 scfm of air and 900 blower horsepower. The ATAD system requires approximately 2,000 scfm of air and and 450 horsepower for the blower energy and jet motive pumps. In 2005 the City of Bowling Green saved approximately $150,000 in power cost based on an electric unit cost of $0.035/kilowatt hour. The Bowling Green electric rate will soon increase to $.06/kWH and save approximately $250,000/yr. Compared to aerobic digestion.

Supernating the biosolids storage tanks became possible after one year. The addition of powdered Bentonite at a dose of 250 Lbs/350,000 gallons resulted in a fairly clear supernatant and enabled the digested biosolids to be concentrated from 2% TS to 6% TS.

In 2007 Bowling Green abandoned liquid land application and began using the existing centrifuge to dewater all the biosolids and gave the biosolids away to a topsoil blender. Cake solids range from 36%-41%. Polymer dose is approximately 9 Lbs active polymer/dry ton.   Producing biosolids cake for topsoil blending reduced the cost of beneficial reuse from approximately $288/dry ton to $80/dry ton. Cost analyzed included the cost of equipment leasing, diesel fuel, electricity, chemical labor and repair. The reduction in application costs is approximately $120,000/yr.

Morehead, Kentucky (3 TPD). This plant was installed as part of a total plant improvement project. The failing anaerobic digesters were converted to ATAD reactors (Figure 11). The feed solids for the ATAD are co-settled primary and WAS

Innovations

- First poured-in-place ATAD reactor concrete cover

Problems

- Low feed solids concentration (2-3%)

Figure 11
Morehead KY ATAD With Poured-In Place Covers

Results

Detailed operating data from the Morehead WWTP are not available. The superintendent reports that the ATAD system reduced the volume of biosolids applied to land by 60% and belt filter press cake solids increased from 15% to 21%. The elimination of anaerobic digester supernatant recycle back to the plant decreased the secondary treatment BOD load to the point that the new aeration blowers are now oversized.

Delphos OH (4.5 TPD) (Figure 12). The Delphos WWTP is a 3 MGD membrane bioreactor (MBR) plant. This plant replaced the old and overloaded trickling filter plant with anaerobic digesters that was adjacent the city park. The feed solids to the ATAD system are 100% WAS with an MCRT from the MBR plant of at least 25 days. The WAS is thickened using a combination gravity belt thickener/belt filter press (GBT/BFP) The ATAD incorporates advances from the earlier ATAD installations, including a cold water/biosolids heat exchanger, a passive heat exchanger and an SNDR. Stabilized biosolids are dewatered with the BFP. The dewatered cake is stored in the dewatered solids storage building and given away to local farmers. The farmers truck the biosolids to their farms at no cost to the City. Alum is used as a coagulant for the BFP.

Innovations

- First ATAD system to stabilize MBR biosolids
- First ATAD system where farmers remove biosolids cake at no cost to the City.
- Heat exchanger placed on solids transfer line instead of on SNDR sidestream line.

Problems

- None reported

Figure 12
Delphos OH ATAD equipment gallery

Results

The Delphos ATAD has performed better than expected. Even though the WAS is from a long MCRT MBR, the VS reduction is 63%. The biosolids cake ranges in dryness from 22% to 26% TS concentration. The old WWTP biosolids did not reliably meet class B standards and were trucked to a lagoon and mixed with other materials by a septic hauler at $.09/gallon. The ATAD biosolids giveaway program reduced biosolids reuse costs by $173,000/yr over the old, non-class B biosolids.

Heart of the Valley, Wisconsin (11 TPD). This ATAD was installed as part of an innovative plant upgrade. The treatment plant was completely reconfigured from a plant with primary treatment followed by a pure oxygen UNOX plant with anaerobic digestion to a primary/secondary plant with Actiflo ballasted flocculation for primary treatment and a Biostyr biological aerated filter (BAF) secondary treatment process.

Innovations

- Treats Actiflo primary solids and Biostyr secondary solids
- First unaerated liquid storage
- First use of an existing anaerobic digester fixed cover as an ATAD cover
- Passive radiator abandoned

Figure 13
Heart of the Valley ATAD

Problems

- None reported

Results

The ATAD system has performed well at Heart of the Valley WWTP, with a 56% TS reduction, 63% VS reduction, and supernating for biosolids volume reduction. The digested biosolids are stored in unaerated storage tanks and land applied as liquid. The increased solids reduction and digested biosolids concentration by decanting has reduced the biosolids hauling cost by $150,000/yr.

Marshall, Minnesota (6 TPD). The Marshall MN WWTF is a 2 MGD WWTP, but has a large influent organic load from a food processor (Cargill). The ATAD system treats co-settled primary and WAS. This installation was designed to replace failing anaerobic digester equipment Figure 14 and 15).

Innovations

- Eliminated cold water/biosolids heat exchanger and replaced it with a “cooling tower” under the SNDR cover. Ambient air is drawn through the headspace to cool the hot biosolids that are sprayed into the headspace, eliminating the need for the water/biosolids heat exchanger. Experience at other plants had shown that the water/biosolids heat exchanger was inefficient because the difference in temperature between the cold (sometimes not so cold) water and the biosolids was insufficient for effective exchange of heat. This evaporative cooling or ‘swamp cooler” has proven to be a more effective means to cool the biosolids and simplifies the design, construction and operation of the SNDR.

Problems

- Low feed solids concentration (3-3.5%)

Figure 14
Marshall MN ATAD With Concrete Cover

Results

The Marshall MN ATAD shows 60% TS reduction, and at least 65% VS reduction. After a year of operation a supernating culture developed, and the digested biosolids can be decanted to appromately 5% TS concentration, compared to 2.5% TS for the old anaerobic digesters. The combination of better solids reduction and thicker solids concentration reduces the volume of biosolids to be land applied by 67% compared to the old anaerobic digesters. ATAD supernatant has a TS content of approximately 5,000 mg/L (0.5%), which is typical for good anaerobic digester supernatant. The plant superintendent reports that the supernatant ammonia concentration is less than 100 mg/L. The City of Marshall WWTF receives $75/acre from the farmers for biosolids application based on the fertilizer value.

Figure 15
Equipment Gallery

DISCUSSION

A summary of ATAD performance for the municipal plants is shown in Table 3.

Table 3
Municipal Plant Volatile and Total Solids Reduction

Plant	Three Rivers	Yorkville	Bowling Green	Morehead	Delphos	Heart of the Valley	Marshall
TS Red.	45	50	61	unknown	55	56	60
VS Red	55	unknown	72	unknown	65	63	65

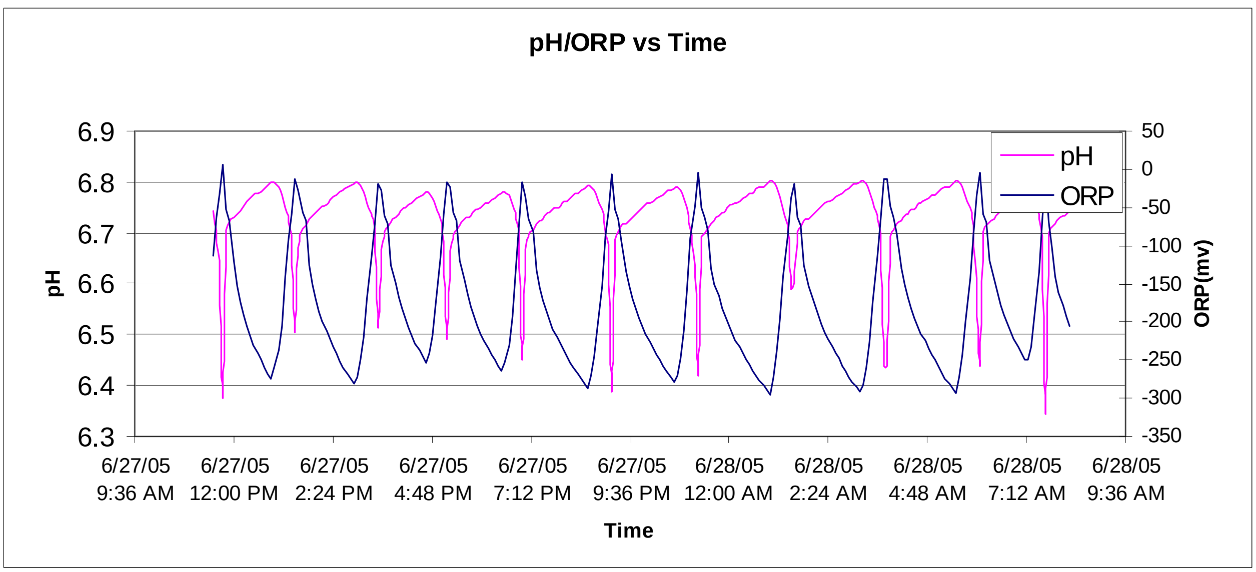
Very good reductions for all sites is shown in Table 3 and exceptional TS and VS removals at Bowling Green, Marshall and Heart of the Valley. These 3 plants all process primary and secondary biosolids. Primary solids are more degradable than secondary solids and are assumed to contribute to the superior performance. The good performance at all these plants indicates that the 2nd generation ATAD performance should perform well at many plants The ATAD system has worked well on 100% WAS as well, even on MBR waste. The lower reductions at Three Rivers is probably due to very thin feed solids and shorter than desired SRT due to high solids flow. Much of the high flow is due to relatively large volume of septage received (approximately 15,000 – 25,000 gallons per day).

A pleasant surprise has been the ATAD system performance at low feed solids. Morehead KY and Marshall have relatively low feed solids concentrations near 3% TS. It was originally thought that feed solids needed to be 4 to 5% TS. Both these facilities have been able to maintain high temperatures at low feed solids.

What's Going On In The SNDR Reactor?

Another reason for improved performance for all the ATAD system installations since Three Rivers WWTP installation is the SNDR reactor. Most of the SNDR reactors are programmed to turn the air off and on based on the ph level in the SNDR reactor as is shown in figure 16.

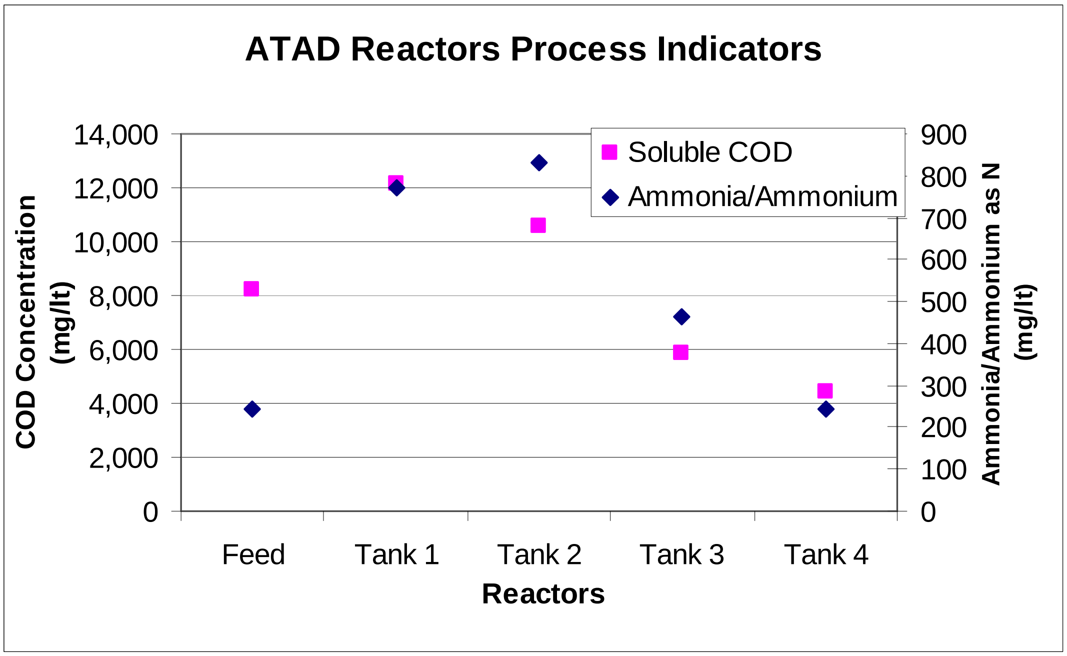
Figure 16
Ph and ORP in Bowling Green SNDR Reactor



The Figure shows the relationship between pH and ORP. Note that the pH and ORP move in opposite directions based on tank aeration. It is interesting to note that the pH rise from dentirification take almost twice as long to occur as the pH drop due to nitrification.

Some other aspects of the SNDR can be seen in the Figure 17 as they affect polymer dosing for dewatering.

Figure 17
Soluble COD Reduction Through SNDR And Storage Tanks, Bowling Green WWTP



The figure shows a 65% reduction in soluble COD and ammonia through the SNDR tank at further storage at Bowling Green, OH.

Why is this important? Novak, Higgins et. al has shown that thermophilic digested biosolids have high polymer demand for effective dewatering. These high polymer doses correlate with the biopolymers lysed from the cells during thermophilic digestion. Biopolymer concentration in biosolids correlates well with the soluble COD concentration. To reduce polymer dose the biopolymers have to be reduced or coagulated. Iron or aluminum salts often are used to coagulate the biopolymers to reduce polymer dose for dewatering. The SNDR reduces the soluble COD by 65% thereby reducing the biopolymers in the digested biosolids, thereby reducing the polymer dose and potentially eliminating the need for metal salt coagulation.

The ammonia reduction also is an important element in improving dewatering. Polymer dose is affected by the ratio of monovalent cations to divalent cations, with divalent cations being more desirable. By reducing the concentration of monovalent cations by denitrification, the water chemistry for polymer effectiveness is improved.

SUMMARY

The second generation ATAD system has proven to be an effective biosolids conditioning process, producing total solids reductions as high as 60% and reliably producing exceptional quality biosolids.

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