ATAD, THE NEXT GENERATION: DESIGN, CONSTRUCTION, START-UP AND OPERATION OF THE FIRST MUNICIPAL 2ND GENERATION ATAD

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ABSTRACT

Autothermal thermophilic aerobic digestion (ATAD) is an effective method to produce a pasteurized (Class A) biosolid. The process has not been well received in the United States because of problems with odors, poor volatile solids reduction, high dewatering costs and inflexible designs. An improved, 2nd generation ATAD design was developed to provide high total solids reduction in a small reactor for industrial biosolids. The improved design has solved the operating and aesthetic problems inherent in the first generation of ATAD. The new unit operates automatically, reduces the total solids by nearly 50%, dewaters well at a reasonable polymer dose with no metal salt addition required and produces no odors other than ammonia. The original plan for solids handling was a dryer, which was quite expensive. Use of the 2nd generation ATAD allowed the use of a much less expensive dryer, which reduced capital and operating expenses. The use of a "dual A" process also eliminated costly redundant equipment.

KEYWORDS

2ND generation ATAD, jet aeration,

INTRODUCTION

Autothermal thermophilic aerobic digestion (ATAD) is an effective method to produce a pasteurized (Class A) biosolid. The process has not been well received in the United States because of problems with odors, poor volatile solids reduction, high dewatering costs and inflexible designs. An improved, 2nd generation ATAD design was developed to provide high total solids reduction in a small reactor for industrial biosolids. The improved design has solved the operating and aesthetic problems inherent in the first generation of ATAD.

This paper will discuss the selection, design, start-up and operation of the first municipal 2nd generation ATAD, which was constructed in Three Rivers, Michigan in 2002.

THE PROBLEM

The City of Three Rivers is a 2.75 mgd primary/secondary WWTP with an design flow of 2.75 mgd, and an annual average flow of about 1.50 mgd. Solids handling consisted of anaerobic digestion, centrifuge dewatering, and landfilling. In 1998 the plant was continually exceeding its' permit limits and emitted noxious odors, which caused a great public uproar and much agitation. A study found the following problems:

- The City had contracted to treat wastewater from a nearby village. The load was greater than expected. The secondary treatment process could not handle the increased carbonaceous biochemical oxygen demand (CBOD) load. In addition, long detention times in the contract community force main caused odors at the plant.
- Large variations in organic loading occured from season to season
- Failing anaerobic digesters produced odorous sludge that did not always meet Class B pathogen requirements and was marginal for vector attraction reduction requirements (VARR).
- The WWTP accepted septage daily. The septage receiving station was less than 100 feet from residences and generated many odor complaints. The septage also contributed to the organic overload, and….
- ODORS, ODORS, ODORS. The sources of odors listed above were a primary complaint of the citizens.

The problems above led to an administrative consent order from the Michigan Department of Environmental Quality (MDEQ). As part of the consent order, the City agreed to increase the plant capacity, eliminate odors, and improve the solids handling

HOW A 2ND GENERATION ATAD WAS SELECTED

The solids handling train was studied because the existing digesters were in need of extensive repair and were not performing well. The study recommended that the plant abandon digestion, use the digesters as holding tanks and use an indirect dryer to produce an exceptional quality biosolid (EQB) that could be used without class B restrictions. Drying undigested solids in a continuous dryer posed several problems, including:

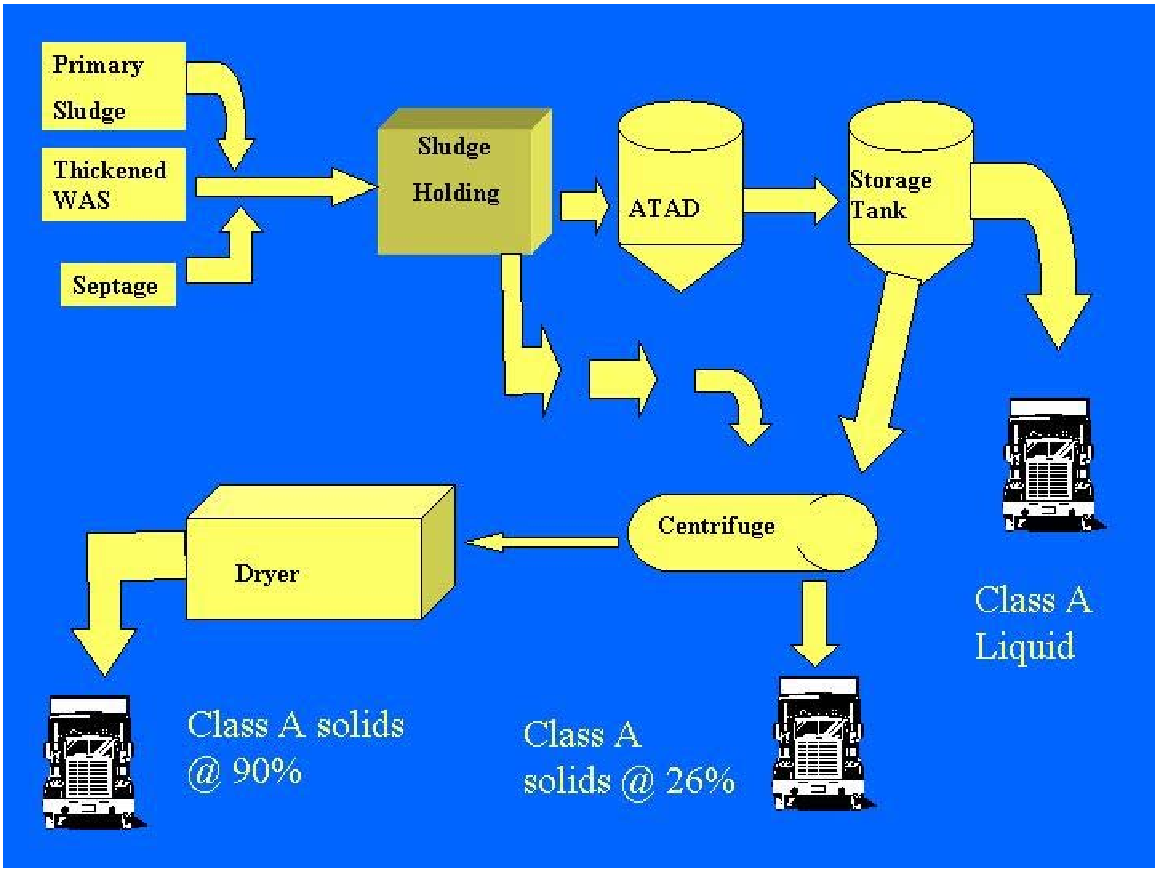
- Odors from the sludge holding tanks and dryer emissions.
- Additional energy (perhaps 25%)is needed to dry undigested solids, as more water is bound up within the bacterial cells.
- The continuous dryers might require periodic round-the clock "campaigns" to avoid excessive thermal stress on the equipment. The Three Rivers WWTP is staffed 10 hr./day. Campaigns would require extra labor cost.
- Sludge dryers are relatively expensive for the size of the plant. Budget prices for dryers were about $1.5 million.

- Because of the odor problems, a redundant centrifuge and dryer might have to be part of the capital improvements, making the project very costly for a city with a depressed economy.

The above problems made it advantageous to stabilize the solids before drying, as odors and redundant equipment could be eliminated. After further study, a 2nd generation ATAD was selected to stabilize the solids which would be a combination of primary sludge, thickened waste activated sludge (TWAS) and screened, degritted septage combined in one holding tank. The ATAD would be chained with a dryer for a "Dual A" biosolids process. The ATAD has many advantages, including:

- The process could be housed in two existing sludge storage tanks and the old sludge truck garage, reducing capital cost.
- All the moving parts were out of the tank
- The process uses reliable, low maintenance pumps and blowers to mix and aerate the sludge. All piping is stainless steel and fiberglass.
- The ATAD would reduce the total solids to be dewatered and dried by 40-50%. This mass reduction made it possible to use an inexpensive (approx. $325,000) indirectly heated batch drier. This chaining of two class A processes actually made the project less expensive to build and operate. (This will be the subject of another paper).
- It eliminated the need for redundant units, as the ATAD and centrifuge would produce EQB cake solids if the dryer were out of service, the ATAD would produce EQB liquid if the centrifuge were out of service, and the dryer would produce EQB biosolids if the ATAD were out of service. No land application permits were required from MDEQ (Figure 1).
- Different types of biosolids would be produced for different potential end users.

Figure 1
Three Rivers Solids Handling Schematic



WHAT IS AN ATAD?

ATAD stands for Autothermal Thermophilic Aerobic Digestion. The ATAD consists of insulated reactor(s), a volumetrically efficient (low air flow) aeration system, foam control devices and transfer piping as required. The aerobic reactions in the digester release sufficient heat to raise the reactor temperature to the thermophilic range, generally from 56^{o}-65^{o} C. To comply with the EPA requirements for time and temperature the ATAD operates on a draw and fill cycle. Hold times based on time and temperature range from 4-20 hours. ATADs have been used in the US almost exclusively to digest TWAS, thickened above 4% TS.

The initial (first generation) ATAD designs are characterized by the following design and operating features (Figure 2):

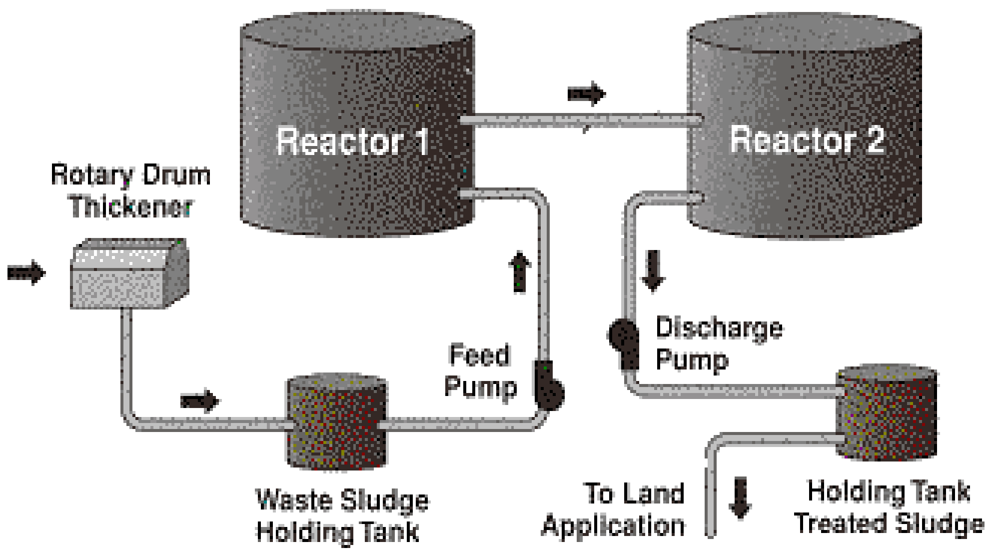
- Aspirating air systems - hollow tube aerators, aspirated pumps or aspirated jet systems .
- 2 or three reactors operated in series
- Short SRT, generally less than 10 days for the whole series of reactors

- Mechanical foam cutters protruding through the tank ceiling.
- An invariable air supply and no aeration control.

This design has several shortcomings, and led to the following operating problems, which hindered the acceptance and use of this technology:

- Insufficient detention time, leading to poor VS reduction
- Poor temperature regulation, which requires the addition of heating and cooling loops in the reactors

Figure 2
First Generation ATAD Schematic



- Insufficient flexibility in some designs. The hollow tube aerator design requires a constant liquid level. The air must be shut off during the draw and fill cycle
- Insufficient oxygen delivery, leading to poor stabilization and ODORS, ODORS, ODORS. In some communities the odors became the focus of local elections.
- Extremely high polymer dose required for dewatering. ATAD sludge is composed of non-flocculent thermophilic organisms, has a high negative charge and a massive demand for cations to promote flocculation. At some installations the polymer cost exceeds $180/ton. The ATAD sludge does, however, dewater very well. The polymer dose can be reduced by the use of

large doses of iron or aluminum salts to satisfy the ATAD biosolids' demand for cations.

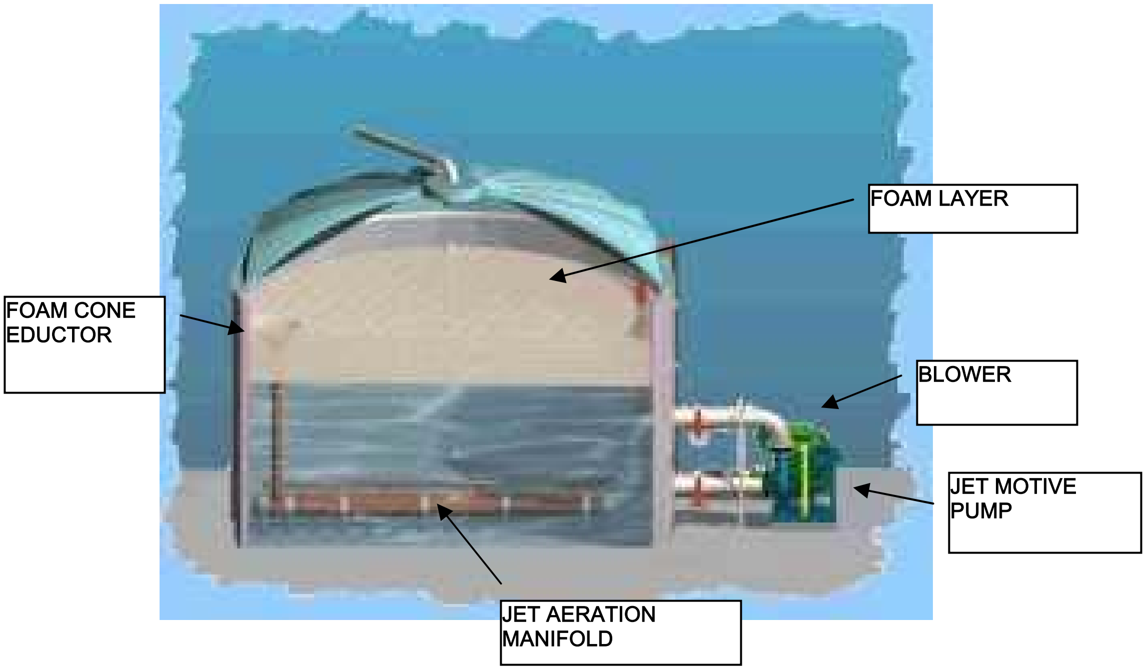
WHAT IS A 2ND GENERATION ATAD?

The 2nd generation ATAD is the logical progression from the initial designs. The key improvements of this design are (Figure 3):

- Single stage operation at 10-15 day SRT to provide a better operating environment.
- Use of a pressurized (blower) jet aeration system. The jet system uses oversized motive pumps to maximize nozzle turbulence, thereby maximizing volumetric oxygen transfer.
- Use of VFD on motive pumps and blowers to vary the oxygen delivery as needed. The pumps and blower speeds are controlled to maintain target oxidation-reduction potential (ORP) values during different phases of the feed cycle, which allows….
- Sufficient variable oxygen delivery to maintain aerobic conditions. The oxygen delivery system eliminates odors, improves VS destruction and improves temperature regulation for the following reasons:
    1. ATAD, with its concentrated feed and slug loading, is a "feast and famine" biological environment typical of most CBOD removal systems. The oxygen requirement is greatest in the first 6 hours after feeding during the "feast" or "burn" cycle. During this time much of the waste is stabilized. The oxygen demand decreases greatly after the burn cycle. Maintaining aerobic conditions during the burn mode improves VS destruction by keeping the thermophilic aerobes functioning.
    2. Being able to reduce the pump speed and airflow when the" burn" mode is complete reduces heat losses, stabilizes the reactor temperature and conserves electricity.
    3. Maintaining aerobic conditions greatly reduces odor generation by eliminating the conditions that produce amines and reduced sulfur compounds. NOTE: The ATAD does produce copious volumes of ammonia, as nitrifying bacteria do not function at thermophilic temperatures.

- Foam control by entraining the foam with digested sludge in a "foam cone" eductor, and spraying the contents back onto the foam layer. NOTE: the foam layer is a normal consequence of protein degradation. A controlled foam layer is beneficial because it helps to insulate the tank. The foam cones can be located outside the reactor for easy maintenance.

Figure 3
2nd Generation ATAD Schematic (Thermal Process)



SYSTEM DESIGN CRITERIA

The Three Rivers ATAD is designed to treat three sources of waste solids listed below and in Table 1:

- Primary sludge at 4.5% TS
- TWAS thickened in a rotary drum thickener at 5% Ts
- Septage, screened and degritted in a combination septage treatment station.
- The sludges are combined in a common well and decanted to remove excess water.

Table 1
Three Rivers, MI WWTP Sludge Quantities

Sludge Type	Concentration	Volume, gpd	Mass, Lbs./day
Primary	4.5%	6,286	2,359
TWAS	5%	7,194	3,000
Septage	1.5%	10,000	1,251
Total after decanting	**4.7%**	**15,200**	**5,958 (652 Lbs. TS decanted)**

The ATAD was designed as a single -stage reactor with an aerated storage tank using existing storage tanks as the reactor and storage tanks shown in Table 2.

Table 2
ATAD Design Criteria and Equipment

Criteria/Equipment	**Value**
Design load	5,958 Lbs./day
Feed TS	4.7
Feed VS	73%
Daily Feed Volume	15,200 gpd
Design SRT	10-14 days
Design TS reduction	50% (60% VS destruction)
Reactor Dimension & Volumes	45' dia. x 22'4" swd each
Liquid level ranges	Reactor - 8-18' Storage - as needed
Feed pumps	2 self-priming chopper pumps-300 gpm @ 50' TDH
Aeration Equipment (ATAD)	Jet Aeration with Blowers 1 pump 10,000 gpm & 33' TDH w/ VFD, 125 hp 2 blowers, 0-400 scfm @ 7 psi w/VFD, 20 hp ea. AOR - 191 lbs/hr max
Aeration Control	By oxidation-reduction potential (ORP)
Foam Control/Sludge Transfer pump	1 pump, 500 gpm @ 50'TDH 2 foam cone assemblies
Aeration Equipment (Storage)	Jet Aeration with Blowers 1 pump, 2,200 gpm @ 17' TDH, 20 hp 1 blower, 400 scfm @ 7 psi, 20 hp
Odor Control	2 stage biofilter. Ammonia is principal odor compound. No reduced sulfur compounds expected

CONSTRUCTION AND DESIGN CHALLENGES

Retrofitting old equipment for a new purpose always requires extra work and compromises. Chief among these were

- When emptied of sludge, the storage tanks had extensive cracking that had to be repaired with epoxy injection. The tank walls were coated with a compound to prevent corrosion of the rebar at the elevated temperatures and pH (above 8.0) in the ATAD and storage tank.
- Both the ATAD and storage tank jet motive pumps would have to pull a suction lift under some conditions. Although not recommended practive, the pumps, a brand normally used the pulp and paper industry, were able to

reprime with an 8-foot suction lift. The reactor normally operates with a slightly flooded suction.

- The garage required extensive modification to accommodate the equipment.
- The precast concrete planks used for the new tank covers were not the correct length and had to be sent back.

START-UP

A photo of the ATAD tank is shown in figure 4. The ATAD system was put into service on April 24, 2001, precisely on the date required by the consent order. There were the usual start-up bugs, which included:

- Polymer make-up and injection problems with the rotary drum thickener using a scavenged polymer make-up system. The drum was frequently blinded, producing a large volume of very thin sludge. The problem was solved by the addition of a traditional polymer injection ring and weighted check valve assembly..
- Broken and plugged seal water lines
- The ATAD has a complex program to control ATAD wasting and feeding. It takes into account evaporation (which can be over 10% of the feed volume) and historical loading trends. Being a new program, it required some real world testing and adjustment.

In addition, it was hoped that the storage tanks would function as a cool down tank. This would allow nitrification to reduce the reactor pH (above 8.0) and to allow the regrowth of flocculent organisms to improve dewatering. The tank functioned in this manner for about 45 days. During this time the digested solids pH dropped from above 8.0 to 7.2-7.3. After the initial period, the storage tank has proven to be too well insulated and operates at temperatures between 48-50^{o} C.

A continuing less-than optimal condition has been the feed sludge solids concentration, which has been less than anticipated. The low solids content has not caused any problems

All things considered, the start-up was a success.

FIGURE 4
ATAD REACTOR, STORAGE TANK AND BIOFILTER

ATAD Equipment Room

Cooldown/Storage Tank

ATAD Reactor with Foam Control (Lower Left of Picture)

Biofilter

THE RESULTS

The ATAD has been in operation for 5 months when this report was written. A summary of important values is shown in Table 3 and in subsequent charts. Discussion of important topics follows the chart.

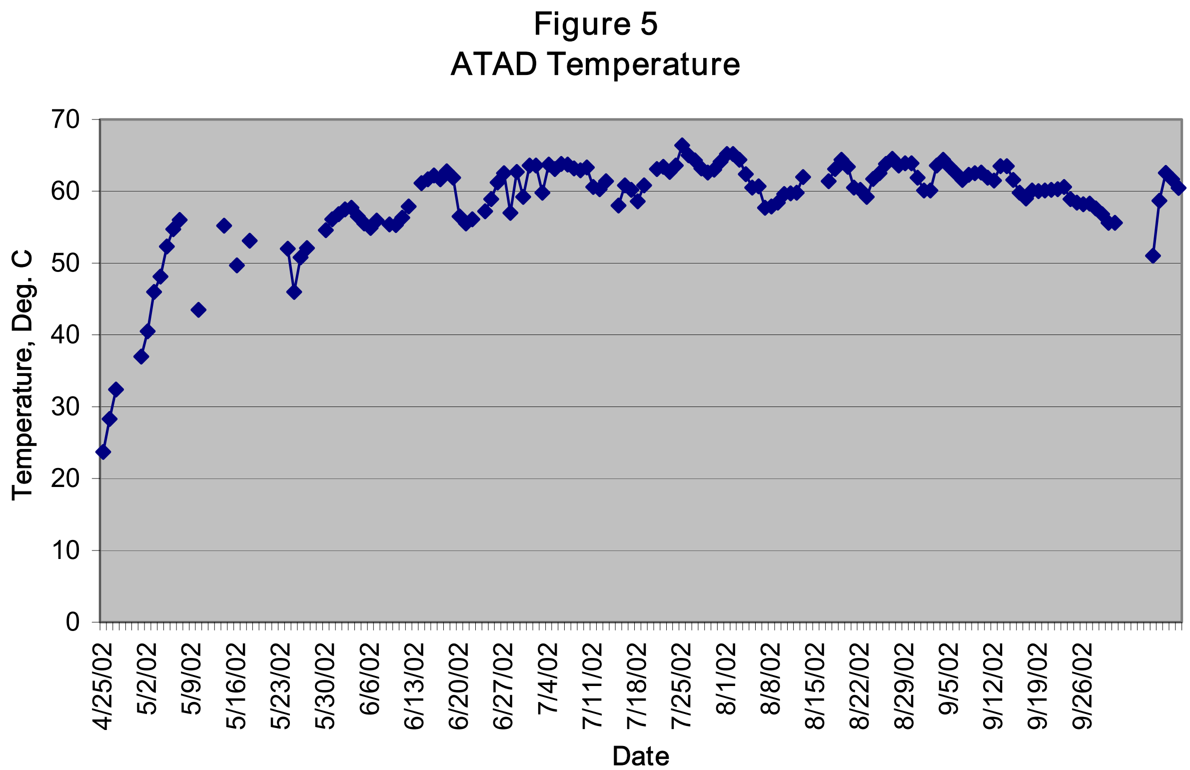
Table 3
Three Rivers ATAD Operating Data,
May-September, 2002

Value/Month	May	June	July	August	September	Average
Flow, gpd	11.984	10,049	15,026	18,859	16,943	14,603
Feed Solids %TS	3.09	3.87	2.33	2.66	2.10	2.8
VS In %	73	74	72	71	69	72
Mass Loading, Lbs/day	3,209	2,870	2,887	4,334	2,930	3,244
Reactor Temp., ^{o} C	51	59	63	62	60	60
TS out, % TS	1.25	1.84	1.81	1.52	1.60	1.62
VS out, %	60	64	62	65	53	60
Mass from Reactor, Lbs./day	1,937	1,768	2,370	2,142	1,730	2,002
TS reduction, %	83	38	18	49	41	46
VS reduction, %	86	47	33	59	51	55
Cake Solids, %	24.8	25.3	27.8	27.6	25.3	26.4

Note: TS and VS reductions based on cumulative monthly mass. The average TS and VS reductions are based on the 5-month cumulative mass in and out.

TEMPERATURE

The ATAD was able to self-heat from an initial temperature of 24^{o} C to a temperature of 56^{o} C in two weeks. Further progress was delayed by thin sludge, equipment start-up problems and control problems that caused shutdowns and excessive sludge transfers from the ATAD reactor to the storage tank. The reactor regained a temperature of 57^{o} C by June 1, reached 63^{o} C on June 15, and has modulated between 58 and 63^{o}C since that time (Figure 5). At these temperatures, the detention time needed for pathogen kill varies between 1 and 9 hours. NO additional heat input was used.



SOLIDS DESTRUCTION

The total and volatile solids destruction for the 5-month initial operating period has been quite good; 46% and 55% respectively as calculated by mass balance. There has, at times, been additional VS reduction in the cool down tank (Figures 6 and 7), but the additional reduction is minor. The figures show that the ATAD operation stabilized in the middle of August. Stable operation shows a consistent and stable mass reduction, with good buffering of process transients.

FIGURE 6
SOLIDS IN AND OUT OF ATAD
(28-DAY MOVING AVERAGES)

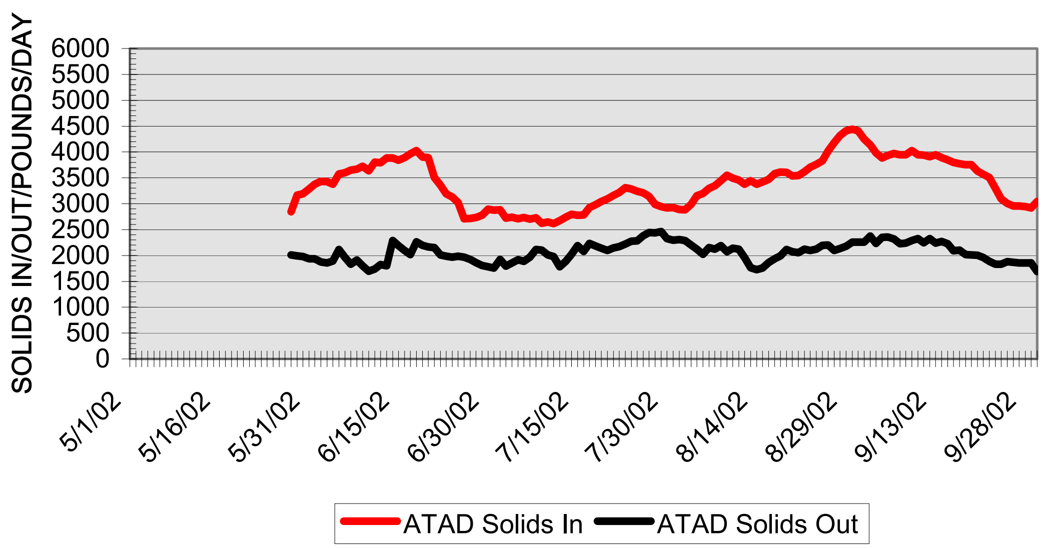
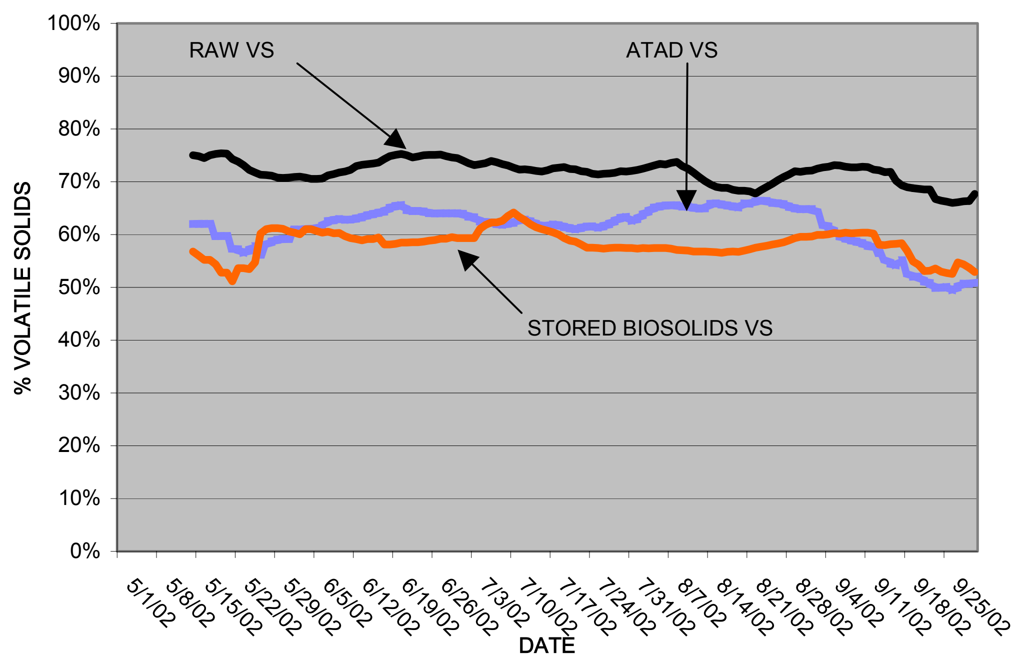


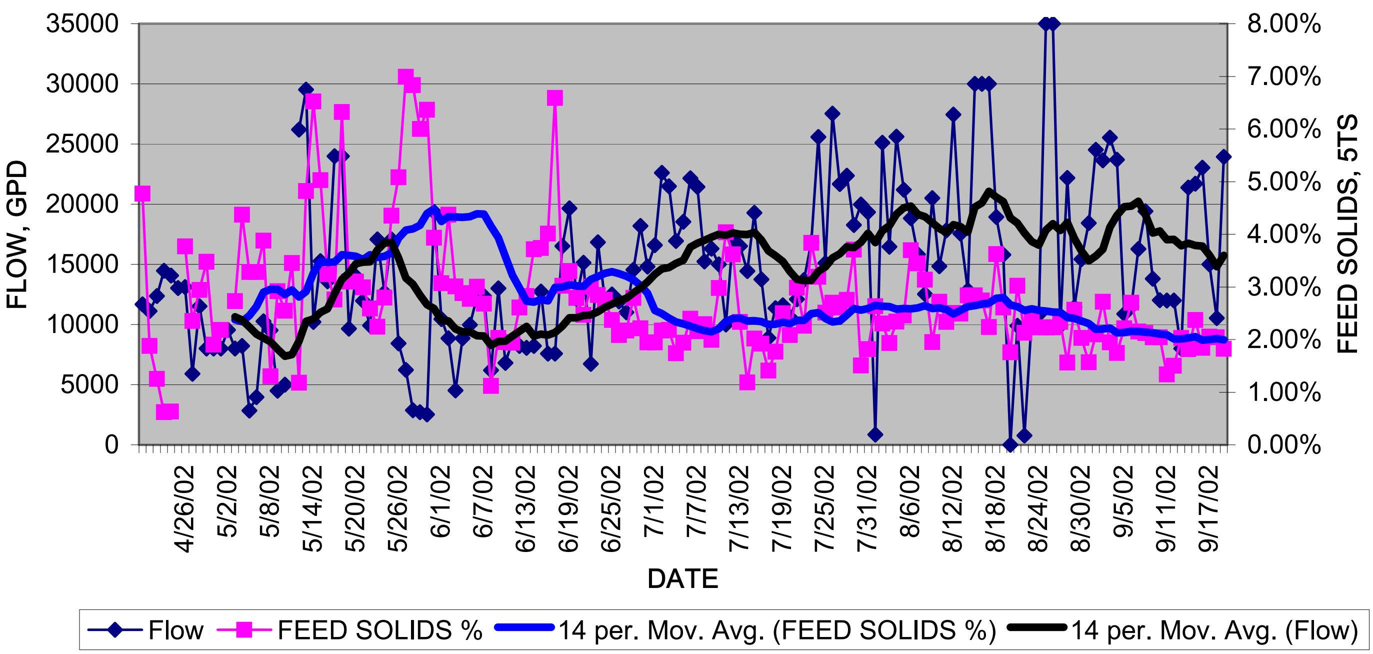
FIGURE 7
RAW, ATAD AND STORED VS%
(14-DAY MOVING AVERAGE)



SEPTAGE, FEED FLOW AND LOADING

In July 2002 the plant resumed receiving septage. The septage is screened and degritted in a combination septage-receiving unit before discharge to the sludge well. The thin material was supposed to be decanted before feeding the ATAD. The mixed sludge is generally not decanted. As a result, the ATAD feed increased from 10,000 GPD to 18,00 GPD (120% of design criterion), and the feed solids decreased from 3.3% to 2.5% (55% of design criterion). See Figure 8. In a first generation ATAD, the decrease in feed solids concentration to nearly 50% of design value would have adversely affected the reactor temperature because of the decrease in energy available per gallon of sludge and the increase in water volume that needs to be heated to thermophilic temperatures. The "double jeopardy" of low solids and high flow would most likely have caused a "death spiral" back to mesophilic conditions. In spite of the high volume and low solids, the 2nd generation ATAD retained temperature and volatile solids destruction. This can, in part, be attributed to the primary and septage solids, which are much richer energy sources than the partly stabilized TWAS usually treated in an ATAD, and in part to lower thermal losses inherent in the design. The septage is a good source of income. At current septage flow of 15,000-21,000 GPD, six days per week, the City will receive over $150,000/yr in revenue charging $0.035/gallon of septage.

FIGURE 8
ATAD FEED,AND TS%



Treating most of the septage in the ATAD improves secondary treatment operation by reducing the load of oil, grease, odorous compounds and other troublesome compounds sent to liquid treatment.

EASE OF OPERATION

The ATAD equipment vendor (Thermal Process) provided the instrumentation and controls to operate the ATAD. After the expected initial software glitches, especially for the waste and feed cycle, the program has operated as advertised. To initiate a waste and feed cycle, the plant operator enters a command at the ATAD control panel. The programmable logic controller (PLC) then calculates the volume to be wasted, taking into account recent loading trends and the evaporation of water from the reactor; wastes the calculated volume from the reactor, and feeds the reactor the entire contents of the sludge well. During the rest of the day, the PLC controls the number of blowers on-line, the blower output and the jet motive pump speed to vary the oxidation pressure to maintain an ORP set point. During the "burn" cycle, the ORP will drop to about -350mV. When the material is stabilized, the PLC controls oxidation to maintain an ORP of near 0 mV.

The PLC also continually monitors the reactor temperature, and calculates the time and temperature required for pathogen kill. When the reactor has accumulated the necessary time and temperature, a green light activates on the control panel, showing that the time and temperature requirements for Class A biosolids have been met.

The ATAD design of pressurized jet aeration allows the reactor to be aerated at all times, and for the reactor level to vary as required. Because of this design, **the volume wasted does not have to match the volume fed,** allowing for more consistent solids retention time (SRT), and the retention of biomass to stabilize high volume or high BOD loads. As shown in Figures 5 and 6, the ATAD operation has stabilized in August 2002, producing very good and consistent results despite highly variable loadings.

DEWATERING

As expected, the ATAD sludge dewaters well. Cake solids improved from 22-24% TS for the anaerobically digested sludge to 26-28% TS for the ATAD sludge. What was totally unexpected was the polymer dose. There was no increase in the polymer dose or polymer cost when the centrifuge switched from anaerobically digested sludge to ATAD sludge. Dewatering costs remained at $40-50/dry ton **with no metal salt addition for flocculation.** Note: The Three Rivers WWTP uses refined ferric chloride (not pickle liquor) for phosphorus removal at the rate of about 15 gallons/day, which is approximately 15 lbs of iron/day. The centrifuge solids capture varies from 93-99%. No change in ATAD cake quality or polymer dose was noted when the cool-down tank temperature rose from the mesophilic to the thermophilic range. Further work will be needed to determine why the sludge dewaters do well without metal salt addition.

ODORS

The ATAD releases copious volumes of ammonia liberated by protein degradation. The off gas ammonia concentration is about 800 ppm. The ammonia is treated in a two-stage biofilter provided by the ATAD vendor. The biofilter consists of a humidification chamber and the biofilter that uses coarse shredded roots as the bio media. There were volatile fatty acid odors for part of one day immediately before the ATAD reached lower thermophilic temperatures (approx. 110^o C). There have been no odors since. Off-gas testing from the ATAD shows no amines or other reduced sulfur compounds. The lack of reduced sulfur compounds such as hydrogen sulfide, amines or mercaptans shows the ATAD aeration system provides sufficient oxygen during the entire digestion cycle.

CONCLUSION

The 2nd generation ATAD is a great improvement over the initial ATAD installations. The Three Rivers project is a very successful installation. It achieved the following objectives:

- Over 50% VS reduction
- Odor-free operation
- Trouble-free operation
- Good dewatering
- Reasonable polymer consumption

And at least three unexpected good results, these being:

- No additional metal salts required for dewatering
- Operation at much higher volumes and much thinner solids than designed
- Trouble-free digestion of large volumes of septage.

The 2nd generation ATAD has performed better than expected, was placed in existing structures, and had a fairly uneventful start-up. The good performance and lack of odors shows that this is truly an advancement of ATAD technology.

The operation with septage should be of particular interest to plant superintendents. Some states have special programs that defray a portion of the cost of structures and equipment needed for septage acceptance and treatment. Part of the capital cost of a 2nd generation ATAD could be subsidized by the septage treatment grant if it is designed to treat septage as well as primary and secondary biosolids.

ACKNOWLEDGMENTS

This project would not have been possible without the prescient vision of Mr. James Rozeboom, superintendent of the Three Rivers, MI WWTP.

I would also like to acknowledge Messrs. Richard Pressley and James Eloff of Thermal Process Systems for their help in making this project possible.

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