

**ENHANCED BIOLOGICAL  
NUTRIENT REMOVAL  
WASTEWATER TREATMENT  
FEASIBILITY STUDY**

**FOR**

**SOUTH MIDDLETON TOWNSHIP  
MUNICIPAL AUTHORITY**

**JUNE 2008 (DRAFT)  
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**PREPARED BY:**



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## **SECTION 1:**

# **INTRODUCTION AND OVERVIEW OF BNR REGULATIONS**

In January of 2005, the Pennsylvania Department of Environmental Protection released the Chesapeake Bay Tributary Strategy (CBTS), which was designed to address and mandate Pennsylvania's commitment for nutrient and sediment reductions within the Chesapeake Bay Watershed, under the Chesapeake 2000 Agreement. The goal of the Chesapeake 2000 Agreement is to remove the Chesapeake Bay from the federal Clean Water Act's list of impaired waters prior to 2013.

As a result, the Pennsylvania Department of Environmental Protection has developed an allocation approach, whereby CAP loadings for Total Nitrogen and Total Phosphorus have been established for each wastewater treatment facility discharging within the Chesapeake Bay Watershed. CAP loadings are the maximum amount of contaminant that can be discharged by the treatment facility, measured in pounds. The CAP loadings will not be increased as the result of facility upgrades or increased treatment capacity. The only potential for increased loadings results from the removal of existing on-lot sewage systems, however the increased loadings are minimal at best. CAP loadings are based on Total Nitrogen effluent concentrations of 6 mg/L and Total Phosphorus effluent concentrations of 0.8 mg/L, and are calculated using the facility's present design flow rate. Compliance with the new mandates requires maintaining annual loadings equal to or less than the CAP loadings that are established, during the period of October 1 to September 30.

The South Middleton Township Municipal Authority provides sanitary sewer service to more than 3,000 residents within South Middleton Township and Monroe Township, including Boiling Springs Pennsylvania. The existing wastewater treatment facility is an extended air activated sludge system, which utilizes long concrete tanks (with aeration) to provide the required treatment. The Authority's wastewater treatment facility has a current design flow of 750,000 gallons per day (0.75 MGD); however, this facility is designed to double its capacity to 1,500,000 gallons per day (1.5 MGD). The additional treatment tankage required to increase the capacity to this level is constructed and available for use. Under the new mandates, the Total Nitrogen CAP loading is 27,396 pounds (annually), while the Total Phosphorus CAP loading is 3,652 pounds (annually). Maintaining compliance with these mandates and regulations will require substantial upgrades to the existing treatment facility.

Based on current analytical data, the Authority discharges approximately 48,218 pounds of Total Nitrogen on an annual basis. The Authority's NPDES permit currently contains a 1.0 mg/L discharge limit for Total Phosphorus. As a result, chemical precipitation of the Phosphorus using aluminum-sulfate is required and results in a Total Phosphorus discharge of approximately 330 pounds on an annual basis.

The Authority has recently received a new NPDES permit, requiring compliance with the new Chesapeake Bay Nutrient Loading regulations. In addition, the treatment facility is located along the Yellow Breeches, a nationally renowned and exceptional quality Pennsylvania fishery. The age and treatment capabilities of the existing treatment facility will make compliance with the Chesapeake Bay Nutrient Loading regulations nearly impossible. Additionally, it is strongly believed that exceptional quality treatment of the incoming waste stream is critical in protecting the Yellow Breeches and its associated wildlife.

As mentioned previously, the Authority's wastewater treatment facility will require substantial upgrades to achieve the nutrient CAP loadings as mandated by the Pennsylvania Department of Environmental Protection, or else purchase credits, which will be discussed later in the report. It is our recommendation that the Authority upgrade the treatment facility utilizing Enhanced Biological Nutrient Removal (EBNR) technology. The upgrades should include construction of the following, which will all be discussed further within this report:

- Screening and grit removal facilities
- Influent pumping station
- Clarifiers
- Filters
- Ultra-violet disinfection facilities
- Digesters
- Waste thickening and de-watering facilities
- Most importantly, the biological treatment process should be converted into a 5-stage Integrated Fixed Film Activated Sludge (IFAS) process for enhanced total nitrogen and total phosphorus removal.

## **SECTION 2:**

# **TREATMENT FEASIBILITY STUDY OBJECTIVE**

Preparing wastewater treatment facilities for the steps necessary to achieve and maintain compliance with the Chesapeake Bay Tributary Strategy regulations is a complex process. It is important that the biological nutrient removal process is reviewed, that all of the possible options are explored and that the potential costs are identified, so that the proper planning, both operational and financial, can take place.

A treatment feasibility study is the initial step in the planning process, as it will guide the Authority with selecting the optimum biological treatment process, as well as the preliminary and tertiary processes including biosolids handling and processing. The following Treatment Feasibility Study has been prepared to accomplish several objectives, as identified below:

- Identify and briefly explain the biological nutrient removal process.
- Identify and briefly explain the treatment processes that are available to effectively achieve biological nutrient removal.
- Evaluate the treatment processes, and identify the most feasible treatment process for South Middleton Township Municipal Authority.
- Provide recommendations for additional aspects of the treatment process, including screening and grit removal equipment, disinfection systems, clarifiers and filters, as well as biosolids digestion and processing technologies.

Throughout the course of preparing this Feasibility Study, the Authority completed a variety of pilot system studies for various aspects of the treatment process, as listed below. The results and analytical data for each of the pilot tests were reviewed and utilized in determining the recommended treatment processes, as part of this report. Full pilot study reports are not included within this report; however they are available at the Authority office for review.

- Biological Treatment (IFAS System –IDI)
- Volute Screw Press (PW Tech)
- Screw Press (Somat Inc.)
- UV Disinfection (Enaqua)
- Disc Filter (Ashbrook)
- Rotary Drum Thickener (Parkson)
- Fan Press (Prime Solutions)
- Centrifuge (Alpha-Laval)(To be completed in July 2010)

## **SECTION 3:**

# **BIOLOGICAL NUTRIENT REMOVAL PROCESSES**

Nitrogen and phosphorus are the primary causes of cultural eutrophication within surface waters. The most obvious signs of this eutrophication occur during the summer months and include low dissolved oxygen, fish kills, murky water, and depletion of desirable flora and fauna. Excessive amounts of these nutrients can also stimulate the activity of microbes, such as *Pfisteria*, which can be potentially harmful to human health. Point sources of nitrogen and phosphorus include municipal and industrial wastewaters discharged into natural waterways.

Nitrogen and phosphorus exist in dissolved and particulate forms, as well as in several chemical forms. Nutrient removal processes include physical treatment (sedimentation and filtration) for particulates, and chemical or biological treatment for dissolved nutrients.

Biological Nutrient Removal (BNR) removes total nitrogen (TN) and total phosphorus (TP) through the use of microorganisms under different environmental conditions within the treatment process.

### **Biological Nitrogen Removal**

Nitrogen occurs in domestic wastewater as ammonia, nitrate, particulate organic nitrogen, and soluble organic nitrogen. The concentration and form of nitrogen typically present in domestic wastewater is shown in Table 3.1 below.

**Table 3.1**

<b>Nitrogen Form</b>	<b>Strong Sewage mg/L-N</b>	<b>Medium Sewage mg/L-N</b>	<b>Weak Sewage mg/L-N</b>
Organic	35	15	8
Ammonia	50	25	12
Total	85	40	20

As identified above, a significant fraction of the nitrogen is present as ammonia, while the remaining nitrogen consists of degradable organics that can be converted to ammonia during the wastewater treatment process, and non-degradable organics that cannot be removed by any biological process. As a result of this, ammonia removal is generally the initial step in total nitrogen removal. Processes for the removal of ammonia include Physical

and Chemical Processes such as air stripping, breakpoint chlorination, ion exchange, and reverse osmosis, as well as biological treatment processes. Unfortunately, the physical and chemical processes for nitrogen removal have proven to be costly, unreliable, and problematic.

The biological processes that primarily remove nitrogen are nitrification and de-nitrification. Nitrification is defined as a two-stage biological process, which occurs under aerobic conditions (in the presence of oxygen). During nitrification, ammonia is oxidized to nitrite by one group of autotrophic bacteria, known as Nitrosomonas. The nitrite is then further oxidized to nitrate by another group of autotrophic bacteria, known as Nitrobacter. Typical aerobic biological activated sludge existing at wastewater treatment plants can be modified to achieve nitrification by extending the mean cell residence time beyond the values used for typical activated sludge processes while maintaining adequate dissolved oxygen concentrations. Additionally, nitrification can be achieved simultaneously with BOD removal processes or it can be achieved as a separate system following BOD removal. Activated sludge systems typically operate at a pH of 6.5 to 8.5, a mean cell residence time of 4 to 6 days and a dissolved oxygen concentration of 1 to 2 mg/L. Nitrification can be accomplished with similar values if the mean cell residence time is extended from 6 to 8 days, thereby being very close to the optimum value for CBOD (carbonaceous BOD) removal.

De-nitrification occurs under anaerobic conditions (in the absence of oxygen), and involves the biological reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas which is released to the atmosphere. De-nitrification can be accomplished by a host of heterotrophic bacteria in the absence of dissolved oxygen. These bacteria use the oxygen in the nitrate, instead of dissolved oxygen, to digest organic material, thereby releasing nitrogen gas as a waste by-product.

Nitrogen removal can be effectively achieved by combining nitrification and de-nitrification in the same process, or it can be accomplished within separate stages. While separate nitrification/de-nitrification systems are effective, the de-nitrification process typically requires the addition of an organic carbon source, such as methanol, Micro-CG, or UniCarb DN, because of the high removal rates of carbonaceous BOD during the nitrification process. For treatment facilities to achieve optimum biological nitrogen

removal it is important to process wastewater through a series of aerobic and anaerobic stages, to ensure complete nitrification and de-nitrification is achieved.

### **Phosphorus Removal**

Total phosphorus comprises soluble and particulate phosphorus. During the 1970's, the influent phosphorus concentration in domestic wastewater was approximately 10-12 mg/L. The change to liquid detergents without phosphates and the ban of phosphates in granular detergents have significantly reduced the phosphorus concentrations in domestic wastewater. However, concentrations of approximately 4-8 mg/L can still be expected. Phosphorus enters the wastewater treatment plant as both organic particles and compounds, or as soluble phosphorus. Particulate phosphorus can be removed from wastewater through the solids removal process; however, to achieve low effluent concentrations, the soluble portion of phosphorus must also be targeted, through either microbial uptake or chemical precipitation.

Chemical phosphorus removal is the process of adding chemicals that cause soluble phosphorus to form insoluble particles that can be separated from water by sedimentation, filtration, or both. Chemical phosphorus removal has been practiced for many years, and is currently used at the existing treatment facility with great success, producing effluent Total Phosphorus concentrations of 0.2 mg/L or less with great consistency. The chemicals generally used include iron salts, such as ferric chloride, and aluminum salts, such as aluminum sulfate, which is currently used at the existing treatment plant. Chemical phosphorus removal offers lower capital costs, and simple chemical storage and feed systems. However, this process produces added solids requiring additional sludge handling, storage, and treatment. The chemicals used to remove phosphorus can be added to primary clarifiers or after aeration basins prior to secondary clarifiers, or both. Chemicals can also be added upstream of separate final clarifiers and/or tertiary filters following biological treatment.

Biological phosphorus removal involves a physical process that results in the growth of a biological population of aerobic heterotrophs capable of storing orthophosphate in excess of their biological growth requirements. Exposing the bioculture of an activated sludge process to an anaerobic-aerobic sequence causes the proliferation of these microorganisms, known as phosphate-accumulating organisms (PAO), within the mixed

liquor. Under anaerobic conditions, the PAO's convert readily available organic matter to carbon compounds called poly-hydroxyalkanoates (PHA). The PAO's use energy generated through the breakdown of polyphosphate molecules to create PHA's. This breakdown results in the release of phosphorus. Under subsequent aerobic conditions, PAO's use the stored PHA's as energy to take up the phosphorus that was released in the anaerobic zone, as well as any additional phosphate present in the wastewater. In addition to reducing the phosphate concentration, the process renews the polyphosphate pool in the return sludge so that the process can be repeated. This anaerobic-aerobic sequence "selects" a large population of phosphorus removing microorganisms and establishes a cycle of uptake and release of phosphorus, which ultimately allows for most of the phosphorus being incorporated into cell bodies to be separated through clarification and removed, together with the phosphorus by wasting the settled activated sludge from the clarifier.

**SECTION 4:**

**IDENTIFICATION OF TREATMENT  
PROCESS ALTERNATIVES**

There are a number of biological nutrient removal treatment process configurations available. Some biological nutrient removal systems are designed to treat only Total Nitrogen or Total Phosphorus, while other processes are designed to treat both. The configuration of the treatment process most appropriate for any system depends on the influent quality, required effluent quality, operator experience, existing treatment processes, and area available for expansion. Although the exact configurations of each system differ, biological nutrient removal systems designed to treat Total Nitrogen must have an aerobic zone for nitrification and an anaerobic zone for de-nitrification, while biological nutrient removal systems designed to treat Total Phosphorus must have an anaerobic zone free of dissolved oxygen and nitrate. The biological nutrient removal system configurations identified within this section include the following:

- I. 4-Stage Bardenpho Process
- II. 5-Stage Bardenpho Process
- III. Modified Ludzack-Ettinger Process (MLE)
- IV. Wuhrman Process
- V. Oxidation Ditch Process
- VI. Vertical Loop Reactor Process
- VII. 3-Stage Phoredox Process (A2O Process)
- VIII. Modified University of Cape Town Process (MUCT)
- IX. Integrated Fixed Film Activated Sludge Process (IFAS)
- X. Westbank Process
- XI. Sequential Batch Reactor Process (SBR)
- XII. Step Feed Process
- XIII. Moving Bed Biofilm Reactor Process (MBBR)
- XIV. Membrane Biological Reactor Process (MBR)
- XV. BioChem Technology

## 4.I. 4-STAGE BARDENPHO PROCESS

The 4-Stage Bardenpho Process is a continuous-flow suspended-growth process with alternating anaerobic/aerobic/anaerobic/aerobic stages, utilized primarily for nitrogen removal. The overall process is similar to a conventional activated sludge process; however, each stage of the process creates specific treatment conditions, as described below. A flow schematic for this process has been included within Attachment A at the end of this report.

The Stage 1 reactor serves as the first anoxic stage. Nitrate rich mixed liquor from the second stage reactor is mixed with influent wastewater in the absence of oxygen. Bacteria utilize the BOD in the influent, reducing the nitrate to gaseous nitrogen, which is released to the atmosphere. Approximately two-thirds of the influent nitrogen is removed within this stage.

The Stage 2 reactor serves as the first nitrification stage. Oxygen is introduced to oxidize the BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled back to the head of stage 1 for de-nitrification.

The stage 3 reactor serves as the second anoxic stage. Nitrate not recycled to stage 1 is introduced, in the absence of air, where it is reduced to nitrogen gas and released to the atmosphere. This stage is designed to produce low effluent nitrate concentrations.

The Stage 4 reactor serves as the re-aeration stage. Subjecting the waste to re-aeration introduces additional oxygen to the mixed liquor, ensuring that it remains aerobic for improved settling within the final clarifier.

### **Advantages**

- ❖ Lower operating costs than other BNR processes.
- ❖ Simple, stable operation (similar to conventional activated sludge process).
- ❖ Requires minimal operator training.
- ❖ Reduced sludge production.

### **Disadvantages**

- ❖ Only capable of phosphorus removal to 1 mg/L.
- ❖ Coagulants required for enhanced phosphorus removal.
- ❖ Will require additional treatment basins to be constructed.
- ❖ Will require tertiary filters.

## 4.II. 5-STAGE BARDENPHO PROCESS

The 5-Stage Bardenpho Process is also a continuous-flow suspended-growth process with alternating anaerobic/aerobic/anaerobic/aerobic stages, however; an additional reactor is used at the head of the plant for both nitrogen removal and enhanced phosphorus removal. The overall process is similar to a conventional activated sludge process with each stage of the process creating specific treatment conditions, as described below. A flow schematic has been included within Attachment A at the end of this report.

The Stage 1 reactor serves as the fermentation stage. Activated sludge consisting of a broad spectrum of organisms is returned from the clarifier to the fermentation reactor. This sludge is mixed with plant influent to produce the appropriate stress conditions that allow large quantities of phosphorus to be removed biologically in the subsequent aerobic stages. Organism stress occurs in the absence of dissolved oxygen and nitrates.

The Stage 2 reactor serves as the first anoxic stage. Nitrate rich mixed liquor from the third stage reactor is mixed with conditioned wastewater from the fermentation reactor in the absence of oxygen. Bacteria digest the carbonaceous BOD in the wastewater by using the bound oxygen in the nitrate, thus reducing the nitrate to gaseous nitrogen, which is released to the atmosphere. Approximately two-thirds of the influent nitrogen is removed within this stage.

The Stage 3 reactor serves as the first nitrification stage. Oxygen is introduced to oxidize the BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled back to the head of stage 2 for de-nitrification. Luxury phosphorus uptake by the organisms also occurs within this stage.

The Stage 4 reactor serves as the second anoxic stage. Nitrates not recycled to stage 1 are introduced, in the absence of air, where they are reduced to nitrogen gas and released to the atmosphere. This stage is designed to produce low effluent nitrate concentrations.

The Stage 5 reactor serves as the re-aeration stage. If the sludge is allowed to become septic, phosphorus could be released in the final clarifier. Subjecting the waste to re-aeration introduces additional oxygen to the mixed liquor, insuring that it remains aerobic for improved settling within the final clarifier. The settled phosphorus rich sludge is returned to the head of Stage 1 for regeneration of the entire process.

### Advantages

- ❖ Lower operating costs than other BNR processes.
- ❖ Simple, stable operation (similar to conventional activated sludge process).
- ❖ Requires minimal operator training.
- ❖ Reduced chemical costs as phosphorus is removed biologically.
- ❖ Reduced sludge production.

### Disadvantages

- ❖ Generally requires significant area for plant expansion.
- ❖ Will require construction of additional treatment basins.
- ❖ Will require tertiary filters.

## **4.III. MODIFIED LUDZACK-ETTINGER PROCESS (MLE)**

The Modified Ludzack-Ettinger Process is a continuous-flow suspended-growth process with an initial anoxic stage, followed by an aerobic stage, used primarily for nitrogen removal. A flow schematic has been included within Attachment A at the end of this report.

Stage 1 serves as the initial anoxic stage. Influent wastewater, return activated sludge from the clarifiers, and nitrate rich mixed liquor from Stage 2 are combined in the absence of oxygen. The influent wastewater provides the necessary BOD and carbon source. The return activated sludge provides the necessary micro-organisms required for de-nitrification. The mixed liquor from Stage 2 provides the nitrate for de-nitrification. Micro-organisms digest the carbonaceous BOD in the influent by utilizing the bound oxygen in the nitrate, thus reducing the nitrate to gaseous nitrogen, which is released to the atmosphere.

Stage 2 serves as the aerobic stage. Oxygen is introduced to oxidize the remaining BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled back to the head of Stage 1 for de-nitrification. Additionally, subjecting the waste to aeration introduces oxygen to the mixed liquor, insuring that it remains aerobic for improved settling within the final clarifier.

### Advantages

- ❖ Reduced operating costs.
- ❖ Simple, stable operation (similar to conventional activated sludge process).
- ❖ Requires minimal operator training.
- ❖ Reduced sludge production.

### Disadvantages

- ❖ Limited phosphorus removal capabilities.
- ❖ Chemical addition required for phosphorus removal.
- ❖ The entire process is driven by de-nitrification, and the micro-organisms required for this process are not very stable and are very sensitive to toxic chemicals and variations in influent wastewater quality.
- ❖ Tendency for increased electrical costs.

## **4.IV. WUHRMAN PROCESS**

The Wuhrman Process is a continuous-flow suspended-growth process which places an anoxic basin between two aerobic stages, used primarily for nitrogen removal. A flow schematic has been included within Attachment A at the end of this report.

Stage 1 serves as the initial aerobic stage. Influent wastewater is mixed with return activated sludge from the clarifiers, in the presence of oxygen. Oxygen is introduced to oxidize the BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Nearly all of the organics in the raw wastewater are consumed to drive the nitrification process.

Stage 2 serves as the anoxic stage. This stage relies on the nitrate produced within Stage 1 as the oxygen source. Since nearly all of the organics in the raw wastewater are consumed to drive the nitrification process, supplemental organic material (ethanol, methanol, etc.) must be added at the head of this stage. Facultative bacteria digest the organic material by utilizing the bound oxygen in the nitrate, thus reducing the nitrate to gaseous nitrogen, which is released to the atmosphere.

Stage 3 serves as the re-aeration stage. Oxygen is introduced to release nitrogen gas bound within the sludge and to freshen the mixed liquor ensuring that it remains aerobic for improved settling within the final clarifier.

#### **Advantages**

- ❖ Simple operation (similar to conventional activated sludge process).
- ❖ Requires minimal operator training.
- ❖ Reduced sludge production.

#### **Disadvantages**

- ❖ Limited biological phosphorus removal capabilities.
- ❖ Chemical addition required for phosphorus removal.
- ❖ The entire process is driven by de-nitrification, and the micro-organisms required for this process are not very stable and are very sensitive to toxic chemicals and variations in influent wastewater quality.
- ❖ Supplemental organic material will be required within Stage 2, requiring purchase and storage of additional chemicals.
- ❖ Tendency for increased electrical costs.

### **4.V. OXIDATION DITCH PROCESS**

The Oxidation Ditch Process is a completely mixed, continuous-flow process using looped channels to create time sequenced anoxic, aerobic and anaerobic zones, used mainly for nitrogen removal. Aeration throughout this process is provided through the use of mechanical aerators. Biological treatment occurs within long elliptical or circular channels, through a series of four zones, as described below. A flow schematic has been included within Attachment A at the end of this report.

Zone 1 is the initial anoxic zone. Return activated sludge from the aerobic digester is combined with the raw wastewater. This provides the necessary micro-organisms for de-nitrification to occur. Activated sludge is added so that the micro-organisms will properly digest the BOD. Nitrate is reduced to nitrogen gas and released into the atmosphere.

Zone 2 is the initial aeration zone. Aeration is provided through mechanical aerators. Introduced oxygen oxidizes the BOD and converts ammonia to nitrate.

Zone 3 is the second anoxic zone. This stage relies on the nitrate produced within Zone 2 as the oxygen source. Again, nitrate is reduced to nitrogen gas and released into the atmosphere.

Zone 4 is the second aeration zone. Aeration is provided through mechanical aerators. Introduced oxygen oxidizes the remaining BOD and converts any remaining ammonia to nitrate for utilization within Zone 1.

#### **Advantages**

- ❖ Blowers are not needed because mechanical aerators are used to provide the necessary oxygen.
- ❖ The extended aeration process provides a stable and reliable operation.
- ❖ Low solids production.
- ❖ Requires very little energy consumption.

#### **Disadvantages**

- ❖ Large tanks with minimal depth are necessary. Large area is required.
- ❖ Not well suited for flows above 1 MGD.
- ❖ Process often requires significant maintenance time and costs.

### **4.VI. VERTICAL LOOP REACTOR PROCESS**

The Vertical Loop Reactor Process is a completely mixed, continuous-flow process, consisting of an upper and lower compartment, separated by a horizontal baffle. The Vertical Loop Reactor process is a design based upon looped reactors operated in series to create time sequenced anoxic, aerobic, and anaerobic zones. A flow schematic has been included within Attachment A at the end of this report.

The typical vertical loop reactor system has two or more rectangular tanks, placed side by side and operated in series. The first tank is used as an aerated anoxic reactor in which an oxygen deficit condition is maintained and the dissolved oxygen levels are kept near 0 mg/L. Commonly, three basins make up a complete Vertical Loop Reactor system, and surface mounted mechanical aerators provide the mixing and deliver oxygen to the activated sludge. The second tank is used as an aeration reactor with a dissolved oxygen of 2 mg/L.

The surface aeration discs establish an over and under mixing pattern, with the flow direction on the surface opposite of the flow direction on the bottom. The surface discs are typically sufficient for mixing the entire tank. Course bubble diffusers in the first quadrant of the lower compartment supply any additional oxygen required by the process. The horizontal baffle prevents the course bubbles from immediately rising to the surface, and forcing the bubbles to travel the entire length of the baffle providing for optimum oxygen transfer and increased treatment.

### **Advantages**

- ❖ Small footprint – less land area required.
- ❖ Common wall construction – lower construction costs.
- ❖ Lengthy aeration detention time.

### **Disadvantages**

- ❖ Phosphorus removal capabilities are limited – chemical coagulation required.
- ❖ Process relies heavily on BOD – supplemental BOD source may be required.

## **4.VII.3-STAGE PHOREDOX PROCESS (A2O Process)**

The 3-Stage Phoredox Process incorporates the technology of the MLE process. However, it is preceded by an initial anaerobic stage, and is capable of both nitrogen and phosphorus removal. The process configuration promotes the selection of bacteria (PAO) that are capable of removing and storing phosphorus at high levels in the aeration zone. The 3-stage Phoredox Process locks in predictable reaction rates by providing separate, dedicated basin volumes for anaerobic, anoxic, and aerobic environments. Dedicated volumes allow for reliable control of each reactor and guarantee predictable removal at optimum process rates. Without dedicated volumes, biomass moving between environments will undergo a gradual transmission while dissolved oxygen and/or nitrate are consumed, representing lost process volume. Additionally, the 3-stage Phoredox Process can be incorporated into an oxidation ditch format, combining the benefits of the oxidation ditch process with the ability to provide biological phosphorus removal. A flow schematic has been included within Attachment A at the end of this report.

Stage 1 is the anaerobic zone. Activated sludge consisting of a broad spectrum of organisms is returned from the clarifier, and is mixed with plant influent in the absence of molecular or chemically available oxygen. Microbes feed on the soluble BOD, producing volatile fatty acids (VFA's) as a by-product. The VFA's are absorbed by the biomass and converted to poly-hydroxyalkanoates (PHA), releasing phosphorus in the process. The net result of these reactions is to flood the mixed liquor with dissolved phosphorus, allowing large quantities of phosphorus to be removed biologically in the subsequent aerobic stages.

Stage 2 serves as the initial anoxic stage. Effluent from Stage 1 and nitrate rich mixed liquor from Stage 2 are combined in the absence of air. The influent wastewater provides the necessary BOD and carbon source. The mixed liquor from Stage 2 provides the nitrate for de-nitrification. Bacteria digest the influent BOD by utilizing the bound oxygen in the nitrate, thus reducing the nitrate to gaseous nitrogen, which is released to the atmosphere.

Stage 3 serves as the aerobic stage. Oxygen is introduced to oxidize the remaining BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled back to the head of Stage 2 for de-nitrification. In this stage, the microbes that released phosphorus in Stage 1 are now replenishing their depleted stores, using the PHA produced earlier as an energy source. The microbes take up substantially greater amounts of phosphorus than were released, reducing the dissolved phosphorus levels to nearly zero. Additionally, if the sludge is allowed to become septic, phosphorus could be released in the final clarifier. Subjecting the waste to re-aeration introduces additional oxygen to the mixed liquor, ensuring that it remains aerobic for improved settling within the final clarifier. The settled phosphorus rich sludge is returned to the head of Stage 1 for regeneration of the entire process.

### **Advantages**

- ❖ Simple operation
- ❖ Generally requires no chemical addition for Phosphorus removal.
- ❖ Oxygen demand is reduced by 30%-40%, lowering operating costs.
- ❖ Produces high quality sludge.

### Disadvantages

- ❖ Phosphorus removal is greatly influenced by nitrate recycle to the anaerobic stage.
- ❖ Higher COD / P ratio is required.

## **4.VIII. MODIFIED UCT PROCESS**

The Modified University of Cape Town Process (MUCT) incorporates the technology of the 3-Stage Phoredox Process. However, a second anoxic stage is added for internal nitrate recycling. This process is capable of both nitrogen and phosphorus removal. A flow schematic has been included within Attachment A at the end of this report.

In the MUCT process the anaerobic stage receives raw influent which is mixed with phosphorus rich anoxic mixed liquor from Stage 2. Microbes feed on the soluble BOD, producing volatile fatty acids (VFA's) as a by-product. The VFA's are absorbed by the biomass and converted to poly-hydroxyalkanoates (PHA), releasing phosphorus in the process. The net result of these reactions is to flood the mixed liquor with dissolved phosphorus, allowing large quantities of phosphorus to be removed biologically in the subsequent aerobic stages. This stage acts as a fermentation tank providing the necessary stress conditions and resulting in substantial phosphorus release.

The anoxic portion of the process is divided into two anoxic reactors, where the first reactor receives activated sludge from the clarifiers which is mixed with influent from Stage 1, resulting in rapid phosphorus uptake by the microorganisms. Phosphorus uptake is critical, as the phosphorus rich mixed liquor is recycled back to Stage 1 for phosphorus release. The second reactor receives influent from Stage 2 which is mixed with nitrate rich mixed liquor from Stage 4, resulting in nitrate reduction to gaseous nitrogen which is released into the atmosphere.

The final stage of the process serves as the aerobic stage. Introduced oxygen oxidizes the remaining BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled to the head of Stage 3 for de-nitrification. If the sludge is allowed to become septic, phosphorus could be released in the final clarifier. Subjecting the waste to re-aeration introduces additional oxygen to the mixed liquor, ensuring that it remains aerobic for

improved settling within the final clarifier. The settled phosphorus rich sludge is returned to the head of Stage 2 for regeneration of the entire process.

#### **Advantages**

- ❖ Increased phosphorus removal as a result of the reduced nitrate concentrations in anaerobic stage.
- ❖ Optimum nitrogen removal through nitrification/de-nitrification process, as well as recycle between stages 3 & 4.
- ❖ Separate anoxic stage for return activated sludge de-nitrification, which protects the anaerobic zone for enhanced phosphorus release.

#### **Disadvantages**

- ❖ Very complex and intensive operation.
- ❖ Additional recycle stream, resulting in additional piping and pumping requirements.
- ❖ Increased construction and operational costs.

### **4.IX. INTEGRATED FIXED FILM ACTIVATED SLUDGE PROCESS (IFAS)**

The Integrated Fixed Film Activated Sludge Process (IFAS) includes any wastewater system that incorporates some type of fixed film media within a suspended growth activated sludge process. The media systems that can be used vary greatly, and can include rope media, looped strand media, sponge cuboids, plastic wheels or packing material of various types. The media can be free floating in the mixed liquor or fixed within the aeration basin on cages or frames. The basic principle behind the IFAS Process is to expand the treatment capacity or upgrade the level of treatment by supplementing the biomass in a suspended growth activated sludge process by growing additional biomass on fixed film media contained within the mixed liquor. The additional biomass allows a higher effective rate of treatment within smaller process tanks, thus making volume available to incorporate de-nitrification and/or biological phosphorus removal within the same tanks. A flow schematic has been included within Attachment A at the end of this report.

Specifically, IFAS systems immerse a solid support media into a basin having suspended biological growth. The support media provides the surface area, which serves to

promote the growth of the attached biomass. The additional biomass provided by placing fixed film media directly into the suspended growth reactor creates additional biological activity within the same basin, without increasing clarifier solids loading, which often limits the treatment capacity of existing activated sludge treatment systems. The result of this combination is an increased overall active biomass, which increases the wastewater treatment capabilities of the system.

As discussed previously, there are several types of media used to fix the biomass in the activated sludge reactor. Rope-type media, also referred to as looped cord or strand media, takes the form of a woven rope with protruding loops that provide a surface for the growth of biomass. Sponge-type media is a free floating media comprised of small cuboids with a specific gravity close to that of water, which are dispersed throughout the mixed liquor, which require the installation of screens to keep the media within the appropriate basin. Plastic media for use within municipal applications generally takes the form of free floating plastic wheels, also referred to as biomass carriers, also requiring the installation of screens to keep the media within the appropriate basin. Packing material media is generally not used for municipal applications.

### **Advantages**

- ❖ Additional biomass for treatment without increasing solids loading on clarifiers.
- ❖ Additional treatment capacity without increasing process tank volume.
- ❖ Improves solids settling.
- ❖ Greater resistance to organic and hydraulic shock loads.
- ❖ Reduced operational costs.
- ❖ Stable sludge production.
- ❖ As loadings increase, additional media can be added to compensate.

### **Disadvantages**

- ❖ Biological phosphorus removal requires additional stages.
- ❖ Requires extensive screening and grit removal for proper operation.
- ❖ Requires additional screens within the treatment process for media retention.
- ❖ Minimal potential for media loss or breakage.

## 4.X. WESTBANK PROCESS

The Westbank Process is a continuous flow suspended-growth process, used primarily for nitrogen removal. However, minor biological phosphorus removal is also achieved. The process consists of numerous cells (stages) as identified below:

- 1) Return activated sludge de-nitrification cell
- 2) Anaerobic cell
- 3) Anoxic Cell 1
- 4) Anoxic Cell 2
- 5) Second aerobic cell

In the Westbank process, wastewater from the primary clarifier is divided into two parts; one part goes to the return activated sludge de-nitrification cell, while the other part goes to the anaerobic cell. Nitrate in the return activated sludge is broken down in the de-nitrification cell utilizing the soluble carbon sources (VFA's) in the wastewater. In the anaerobic cell, phosphorus is released from the microorganisms with the assimilation of VFA's that are from the wastewater and the previous de-nitrification cell. In the subsequent anoxic cells, the nitrate in the nitrified mixed liquor is broken down into nitrogen and oxygen. In the final aerobic cell, organic material removal, nitrification and phosphorus uptake by the microorganisms takes place. A flow schematic has been included within Attachment A at the end of this report.

### **Advantages**

- ❖ Reduced sludge production
- ❖ Well suited for small to medium flow facilities (.1 MGD – 1 MGD)
- ❖ Stable during flow variations and shock loads.

### **Disadvantages**

- ❖ Only capable of nitrogen removal to 6 mg/L
- ❖ Only capable of biological phosphorus removal to 1 mg/L
- ❖ Very complex operational requirements
- ❖ Requires primary clarification
- ❖ Additional carbon source is often required.

#### **4.XI. SBR PROCESS**

The Sequential Batch Reactor (SBR) process is a fill and draw, suspended-growth activated sludge process, used primarily for nitrogen removal. Enhanced biological nutrient removal has caused the evolution of continuous flow SBR treatment processes. SBR's are very flexible, relatively inexpensive and very efficient treatment systems for small to medium size treatment facilities. The ability to vary the duration of the aerobic and anaerobic phases of the cycle provides the necessary flexibility to obtain optimum nitrogen removal rates. SBR's can be modified for biological phosphorus removal through the use of a large batch reactor with a re-seeding anaerobic zone. Two particular processes are identified in the section.

The Modified Sequencing Batch Reactor (MSBR) process, by Aqua Aerobics, incorporates multiple reactor cells to provide a variety of treatment techniques. The design configuration can range from a three-cell configuration to provide oxidation and clarification to a seven-cell configuration for enhanced biological nutrient removal. All MSBR systems will include two sequencing cells and a number of other cells with specific functions. The sequencing cells are ideally equipped to assume multiple functions including anoxic mixing, aerobic mixing, quiescent settling, sludge wasting, and clarification. A flow schematic has been included within Attachment A at the end of this report.

The Intermittent Cycle Extended Aeration System (ICEAS), by ABJ, is a modification of the traditional SBR process, allowing continuous flow of wastewater into the basin. Influent flow to the basins is not interrupted during the settle and decant phases, or at any time during the operating cycle. Influent is received continuously during all phases of the cycle, allowing the process to be controlled on a time basis, rather than flow. The ICEAS Basin is divided into two zones, the pre-react zone and the main react zone. The influent flows continuously into the pre-react zone and is directed under a baffle wall into the main react zone. The main react zone is used to provide the nitrification and denitrification requirements, as well as the clarification and sludge settling. A flow schematic has been included within Attachment A at the end of this report.

### Advantages

- ❖ Continuous flow system.
- ❖ Increased sludge flocculation and improved settling.
- ❖ Effective nitrification/de-nitrification.
- ❖ Fully automated control system.

### Disadvantages

- ❖ Filtration is often required for enhanced phosphorus removal.
- ❖ Susceptible to “wash-out” during peak flow periods.
- ❖ Increased operational costs versus other BNR processes.
- ❖ Retro-fit from Activated Sludge Process to SBR Process is often complex and requires substantial capital improvements.

## **4.XII. STEP FEED PROCESS**

The Step Feed Process is a continuous-flow suspended-growth treatment process with alternating anoxic and aerobic stages. However, influent flow is split to several feed locations and the recycle sludge stream is sent to the beginning of the process. The percentage of influent flow that is directed to each step of the process impacts the overall system characteristics and performance. In general, by directing the influent flow to several locations and directing the return activated sludge to the beginning of the system, a higher solids retention time is achieved providing enhanced treatment. This higher retention time is often achieved without increasing the aeration tank MLSS, so the solids loading to the clarifiers is not increased. The flow progression through numerous anoxic and aerobic stages provides for enhanced nitrification / de-nitrification, resulting in significant nitrogen removal. Biological phosphorus removal is limited because of the lack of recycle streams and the biological requirements of the numerous nitrification/de-nitrification zones. A flow schematic has been included within Attachment A at the end of this report.

Although the Step Feed Process has a relatively small footprint for a suspended growth process, it is more complex than standard activated sludge processes and presents a variety of unique operational challenges for optimal operation.

### Advantages

- ❖ Relatively small footprint.
- ❖ Complete nitrification/de-nitrification process.
- ❖ Decreased solids loading to clarifier.
- ❖ Recycle pumping is not necessary.

### Disadvantages

- ❖ Complex operation.
- ❖ Direct carbon feed required to each anoxic zone.
- ❖ Foaming can be problematic in the initial zones.
- ❖ Biological phosphorus removal is limited.

## **4.XIII. MOVING BED BIOFILM REACTOR PROCESS**

The Moving Bed Biofilm Reactor Process (MBBR) is a direct derivative of the Fixed Film Activated Sludge Process, and therefore will only be discussed briefly. The MBBR process utilizes the advantages of activated sludge in conjunction with biofilm carrier elements that are made from polyethylene with a density slightly less than water. The elements are designed to provide a large protected surface area for the biofilm and optimal conditions for the bacteria culture when the elements are suspended in water. The MBBR Process offers a very simple operating treatment system while having no return sludge from the clarifiers, the ability to handle large flow and load changes while maintaining its treatment efficiency. The process allows the retention of slow growing nitrification bacteria within the aerobic reactor, while not being washed out during cold temperatures or hydraulic events since they are housed within specially designed bioreactors.

### Advantages

- ❖ Increase capacity within existing basins.
- ❖ Easy to control and operate.
- ❖ Biofilm carriers rarely clog.
- ❖ No sludge return is necessary.
- ❖ Improved nitrification/de-nitrification for existing activated sludge facilities.

### **Disadvantages**

- ❖ Element loss is possible through elevated (storm) flows.
- ❖ Biological phosphorus removal requires additional stages.
- ❖ High influent BOD loadings are required to drive process.
- ❖ Requires extensive screening and grit removal for proper operation.

## **4.XIV. MEMBRANE BIOLOGICAL REACTOR**

Membrane Bioreactors use membrane-type filtration units, instead of clarifiers, that are placed either directly into the activated sludge basin or are located outside of the basin. A typical MBR system consists of separate aeration tanks, followed by the membrane filtration tanks. The membrane elements separate the mixed liquor solids from the treated effluent which is drawn through the membrane by either gravity or pumps. The permeability of the elements is maintained by continuous air scouring of the membrane surface. Excess mixed liquor solids are wasted directly from the aeration tanks. A secondary clarifier is not required for solids separation. Thus clarifier solids' loading is not an issue so this process is able to operate at very high MLSS levels, in many cases as high as 10,000 mg/L. The membranes vary from hollow tube filters to flat panels.

Membrane bioreactors require several cleaning cycles. Typically, there is a frequent but short duration backwash using filtered wastewater to flush solids from the membrane surface. Periodically, a more extensive backwash is performed with chemical cleaning agents. The more extensive cleaning operation, where the membrane is removed from service and washed in a chemical bath, is much less frequent and typically only required every 6-12 months.

### **Advantages**

- ❖ Low turbidity and suspended solids.
- ❖ Low effluent phosphorus due to complete retention of solids.
- ❖ No final clarification required.
- ❖ Complete PLC based control system.
- ❖ Supports extremely high mixed liquor suspended solids.

### **Disadvantages**

- ❖ Requires significant capital expenditure.
- ❖ Requires a complex screening and grit removal system.
- ❖ Filters are subject to bio-fouling.
- ❖ Foaming is frequently experienced within the bioreactor.
- ❖ Stacked units create a serious maintenance problem.
- ❖ External cleaning of the membrane units is extremely maintenance intensive.

## **4.XV. BIOCHEM TECHNOLOGY**

BioChem is a provided of technology for monitoring, controlling, and optimizing the wastewater treatment process. The main focus of the technology is the BIOS control panel, which performs numerous tasks. BIOS uses a mathematical model to build a virtual bio-reactor inside of the computer. BIOS continuously monitors pollutant loadings to the wastewater treatment plant and calculates optimum control parameters. BIOS then feeds these parameters to the operators, suggesting changes to the set-points, or it can automatically change the set points within the SCADA system.

### **Advantages**

- ❖ Optimizes equipment operation, theoretically reducing energy and maintenance costs.
- ❖ Continuously monitors influent loadings and stores data for as long as ten years.
- ❖ Provides operational recommendations to operators.

### **Disadvantages**

- ❖ Capital costs for system are extremely high.
- ❖ Most SCADA systems can perform similar functions, at lower costs.
- ❖ System is mainly designed for systems 5 MGD and larger.
- ❖ No process guarantees are provided, when used in conjunction with other SCADA systems.

## **SECTION 5:**

# **EVALUATION OF TREATMENT PROCESS ALTERNATIVES**

The purpose of this section is to evaluate the above mentioned biological treatment processes, and identify the most feasible process for the Authority. Discussion regarding nutrient trading, and the feasibility of utilizing this process, will be covered in Section 7.

Thorough evaluation of the available biological nutrient removal processes requires investigation of several factors including: influent wastewater characteristics, effluent regulations and compliance requirements, biological capabilities of the treatment processes, area available for expansion, ability to utilize the existing treatment basins, and financial costs including up-front capital costs, energy and maintenance expenses. It is important to mention again that in order to maintain compliance with the Chesapeake Bay Tributary Strategy requirements, and sufficiently protect the receiving waters of the Yellow Breeches, it is recommended that the South Middleton Township Municipal Authority achieve enhanced biological nutrient removal (TN of 3mg/L and TP of 0.4 mg./L).

Examination of the influent wastewater characteristics is an important step in determining the most feasible biological treatment process. The strength of the influent wastewater will help to determine the need for supplemental chemical addition, as well as the complexity of the biological treatment process that is required. Of particular importance is the influent BOD (biochemical oxygen demand). BOD is a measure of the quantity of oxygen used in the biochemical oxidation of organic matter, essentially the strength of the wastewater. In general, influent BOD concentrations should range between 180 and 200 mg/L (or greater) in order to ensure that the biological nutrient removal processes are successful in removing pollutants to PADEP established discharge limits. This is even more critical when enhanced biological nutrient removal is required. Since January of 2006, the influent BOD at the Authority's treatment facility has averaged 157.9 mg/L; however; numerous weekly readings have been below 150 mg/L, and many readings have been below 100 mg/L. For this reason, it is very likely that a supplemental carbon source will be required to increase the strength of the wastewater and provide the food required to effectively drive the enhanced biological treatment process. Numerous supplemental carbon sources are available, however; we would recommend Micro-CG, UniCarb DN or methanol. All of these were utilized during the pilot study, which will be discussed in greater detail in Section 6. Micro G and UniCarb DN are preferred over methanol, due to lower cost,

operator safety and storage concerns associated with methanol, however these require higher feed rates and can be expected to generate approximately 5% more sludge than methanol. All three supplemental sources are commonly used in the wastewater industry.

Additionally, influent concentrations of Total Nitrogen, Total Phosphorus, TKN (total kehldahl nitrogen), and Total Suspended Solids play a critical role in the selection of the most feasible biological treatment process. Since January of 2006 the influent concentrations of these contaminants are as follows, Total Nitrogen 40.8 mg/L, Total Phosphorus 5.88 mg/L, TKN 40.10 mg/L, and Total Suspended Solids 242.70 mg/L. Influent wastewater characteristics of this type and strength predominantly require biological processes with long detention times, ample biological activity (micro-organisms), and multiple periods of aerobic and anaerobic treatment. These treatment characteristics are most commonly found in the following biological treatment processes; Integrated Fixed Film Activated Sludge (IFAS), Moving Bed Biofilm Reactor (MBBR), and 5-Stage Bardenpho Process. These treatment processes provide extended detention times, elevated biological activity, and multiple periods of aerobic and anaerobic conditions. Attachment B “Wastewater Characteristics” provides a compilation of the influent wastewater characteristics, as well as the effluent residuals for a period from January 2006 to present, including ammonia, nitrate, nitrite, TKN, total nitrogen, total phosphorus, BOD, CBOD (carbonaceous biochemical oxygen demand), and TSS (total suspended solids). In addition, Attachment B contains spreadsheets and charts identifying the current removal rates for Total Nitrogen and Total Phosphorus at the existing treatment facilities.

As mentioned previously, it is recommended that the South Middleton Township Municipal Authority achieve enhanced biological nutrient removal. Enhanced biological nutrient removal means reducing the Total Nitrogen concentration to 3 mg/L or less and the Total Phosphorus concentration to 0.4 mg/L or less. Under the new mandates, the Total Nitrogen CAP loading is 27,396 pounds (annually), while the Total Phosphorus CAP loading is 3,652 pounds (annually). Maintaining compliance with these mandates and regulations will require substantial upgrades to the existing treatment facility. Additionally, the Authority’s facility is predicted to double its capacity to 1,500,000 gallons per day (1.5 MGD) within the next twenty years. The additional treatment tankage required to increase the capacity to this level is constructed and available for use once; however, the established cap loadings will not be increased, requiring enhanced biological treatment to continually

maintain compliance. Based on current analytical data, the Authority discharges approximately 48,218 pounds of Total Nitrogen on an annual basis. The Authority's NPDES permit currently contains a 1.0 mg/L discharge limit for Total Phosphorus. As a result, chemical precipitation of the Phosphorus using aluminum-sulfate is required and results in a Total Phosphorus discharge of approximately 330 pounds on an annual basis. This process must be continued in order to maintain compliance with the new effluent requirements.

Biological capabilities of the potential treatment processes are a critical factor in the evaluation process. Many biological nutrient removal processes are only capable of achieving effluent concentrations of Total Nitrogen up to 6 mg/L and Total Phosphorus concentrations of 1 mg/L. The need to achieve enhanced biological nutrient removal eliminates several of the potential processes, including 4-Stage Bardenpho, MLE, Wuhrman Process, Oxidation Ditches, 4-Stage Phoredox (A2O), Modified UCT, Westbank Process, Modified SBR, and Step Feed. The following processes are capable of enhanced biological nutrient removal: Integrated Fixed Film Activated Sludge (IFAS), Moving Bed Biofilm Reactors (MBBR), Membrane Biological Reactors (MBR), and 5-Stage Bardenpho. A complete identification of the treatment process capabilities is included at the end of the report in Attachment C, Comparison of Biological Nutrient Removal Processes.

The area available within the existing site is also a key factor in determining the most feasible biological treatment process. The existing treatment facility is to some degree "land locked" as the East Branch of the Yellow Breeches flows along the western and northern perimeter of the property, and the remainder of the property is surrounded by wetlands which are prone to significant flooding during heavy rain events. As a result, it is critical that the biological treatment process be situated within the boundaries of the existing fence. There is a land available in the area of the administrative office; however, this area will be best used for handling and processing of biosolids. Many of the possible biological treatment processes will require extensive construction of additional tanks and buildings. Not only will this require significant space, but it will also add significantly to the overall project costs.

As previously stated, the Authority's facility is predicted to double its capacity to 1,500,000 gallons per day (1.5 MGD) within the next twenty years. The additional treatment tankage required to increase the capacity to this level is constructed and available for use.

For this reason, it is important that as much of the existing treatment tankage be utilized as possible, as this will reduce the overall construction costs and reduce the extent of additional tankage required for the expansion when permitted by PADEP. With this in mind, three processes appear to be the most feasible, including Integrated Fixed Film Activated Sludge (IFAS), Moving Bed Biological Reactors (MBBR), and Membrane Biological Reactors (MBR).

Financial costs including capital costs, energy and maintenance costs also play a critical role in the selection of the most feasible biological treatment processes. A project of this magnitude will ultimately require significant funds to be borrowed, leading to substantial debt service and unavoidable rate increases. For this reason, the most feasible processes will be those that utilize the existing treatment tankage, require the least amount of additional land and construction, and provide the best treatment for the lowest annual expenses. A complete identification of the treatment process capabilities, capital costs and annual costs is included at the end of the report in Attachment C, Comparison of Biological Nutrient Removal Processes.

After evaluation of the available biological treatment processes, we recommend that the Authority utilize the following process: Integrated Fixed Film Activated Sludge combined with Moving Bed Biofilm Reactor Technology. A complete description and discussion of the selected process is included below.

## **INTEGRATED FIXED FILM ACTIVATED SLUDGE/ MOVING BED BIOLOGICAL REACTOR PROCESS**

The most feasible process for the South Middleton Township Municipal Authority is the integrated fixed film activated sludge process, incorporating moving bed biofilm reactor technology. This process is extremely attractive as it allows for enhanced biological nutrient removal within a compact footprint, utilizing the existing treatment system tankage, including the existing settling tanks. Estimated energy consumption and operation and maintenance costs are the lowest of the evaluated processes. Additionally, this process will be considered an innovative technology by PADEP, thus allowing the possibility of Innovative Technology grant funding.

The Moving Bed Biofilm Reactor Process (MBBR) is a direct derivative of the Fixed Film Activated Sludge Process, which utilizes the advantages of activated sludge in conjunction with biofilm carrier elements that are made from polyethylene with a density slightly less than water. The elements are designed to provide a large protected surface area for the biofilm and optimal conditions for the bacteria culture when the elements are suspended in the mixed liquor. The MBBR Process offers a very simple operating treatment system, it has the ability to handle large flows and load changes while maintaining its treatment efficiency. The process allows the retention of slow growing nitrification bacteria within the aerobic reactor, which will not be washed out during cold temperatures or storm events since they are attached within specially designed polyethylene biomedica that is retained within the reactor tanks.

The biological process can be designed to utilize the two existing digesters, the two existing aeration basins and the two existing secondary settling tanks, effectively utilizing all of the existing treatment tanks and requiring a minimal amount of additional construction associated with the biological treatment process. The existing tankage should be divided into five separate zones, including an anaerobic zone, pre-anoxic zone, aerobic IFAS zone, a post anoxic zone, and a re-aeration zone. The approximate volume of each reactor for this process is included in Table 5.1 below. Please refer to Attachment D, Conceptual Process Layout, for a conceptual layout of the IFAS/MBBR process including biosolids handling and processing.

**Table 5.1**

<b>Reactor</b>	<b>Process Train #1 Volume (gallons)</b>	<b>Process Train #2 Volume (gallons)</b>
Anaerobic Zone	71,800	71,800
Pre-Anoxic Zone	65,000	65,000
Aerobic IFAS Zone	240,000	240,000
Post-Anoxic Zone	85,400	85,400
Re-Aeration Zone	24,700	24,700
APPROXIMATE TANK VOLUMES		

The influent must first be properly screened to remove coarse suspended particulate matter. Grit removal should also accompany the screening process to remove the grit and heavy inorganic material from the waste stream before entering into the biological treatment process. Both of these processes will be discussed in greater detail within Section 8.

As previously stated, the existing tankage should be divided into five separate zones, including an anaerobic zone, pre-anoxic zone, aerobic IFAS zone, a post anoxic zone, and a re-aeration zone as described below. Please, refer to Attachment D “Conceptual Process Layout” for visual representation of the process.

### **Anaerobic & Pre-Anoxic Reactors**

The anaerobic and pre-anoxic reactors are completely mixed reactors that are provided to accomplish first stage de-nitrification, converting nitrate nitrogen into nitrogen gas. Nitrified wastewater will be recycled back to the pre-anoxic reactor from the final aerobic IFAS zone at a rate of approximately four times the influent flow rate.

### **Aerobic Reactors**

The aerobic reactors must be completely mixed activated sludge reactors which will accomplish the removal of carbonaceous BOD and nitrification to convert ammonia-nitrogen to nitrate-nitrogen. Biofilm carrier elements will be added to these aerobic reactors to increase the active biomass without the need for additional tank volume. Additional carrier elements can be added in the future to increase the treatment capacity within the same volume. Oxygen transfer within the aerobic reactors will be accomplished by coarse bubble diffusers. Dissolved oxygen levels within the aerobic reactors will be maintained between 2.0 and 3.5 mg/L, which is set by adjusting the speed of the blowers in conjunction with a complete D.O. control system.

### **Post-Anoxic Reactor**

The post-anoxic reactor is a completely mixed de-nitrification reactor which will accomplish final nitrate-nitrogen conversion and removal by biological de-nitrification. Mixers will be utilized to completely mix this reactor. A supplemental carbon source, as identified previously in this section, is required within this basin to promote complete de-nitrification.

## **Re-Aeration Reactor**

The final reactor, the re-aeration reactor, is a completely mixed reactor designed to supply D.O. to the wastewater and strip the residual nitrate and excess BOD before leaving the biological treatment process and flowing to the final clarifiers, as will be discussed in Section 8. Oxygen transfer will be supplied through coarse bubble diffusers, and D.O. levels between 1.5 mg/L and 2.5 mg/L will be maintained by adjusting the speed of the blowers in conjunction with a complete D.O. control system.

### **Process Advantages**

- 1) The IFAS/MBBR process employs the use of biomass carriers to support a high concentration of attached biomass. The attached-growth biofilm carriers have a very high surface-to-volume ratio, allowing for a high concentration of biological growth to thrive within the internally protected areas. The sloughed or dislodged biomass from the biofilm carriers will remain suspended within the fluidized fixed film reactor, and is continuously removed from the process by the exiting flow stream.
- 2) Increased nitrification occurs through biofilm retention within the basin. Heterotrophs on the biofilm carriers have extended retention time and proliferate resulting in consistently low effluent BOD<sub>5</sub>, ammonia, and complete nitrification.
- 3) Improved process stability during peak flow conditions occurs as a result of the retention of biomass in the treatment basin.
- 4) Reduced capital and construction costs are realized because all of the existing treatment tankage is utilized with the biological process, eliminating the need for additional construction of biological treatment units.
- 5) Reduced annual energy costs are the results of the blowers and pumping equipment speeds being controlled with variable frequency drives to allow for reduced speeds down during low flow periods.
- 6) No increase in annual operations and maintenance costs are anticipated because no additional operation staff will be required; and regular treatment plant maintenance is no more complex than the current treatment facility.

This process is anticipated to generate effluent concentrations as follows; Total Nitrogen 3 mg/L and Total Phosphorus 0.6 mg/L. As a result, we recommend new circular clarifiers and tertiary filtration to ensure the Total Nitrogen concentrations and reduce the Total Phosphorus concentrations and continually achieve enhanced biological nutrient removal. Recommended process manufacturers include Siemens, Kruger, and Entex.

As mentioned previously, a pilot study for this process has been completed. The pilot study will be discussed in greater detail within Section 6.

## **SECTION 6:**

# **IFAS/MBBR PILOT STUDY**

## **INITIAL STUDY**

In October of 2008, the Authority authorized an IFAS/MBBR pilot study utilizing a 5-stage METEOR ActiveCell system as provided by Infilco-Degremont Technologies. The main goals of the pilot study were identified as follows:

- Determine the ability of the process to achieve EBNR results.
- Determine the effectiveness of the process during the coldest months of the year.
- Determine the ability to biologically reduce Total Phosphorus.
- Identify the effectiveness of potential alternative carbon sources.
- Provide experience for the operational staff utilizing this type of technology.

The unit arrived at the treatment facility in the middle of November 2008, and installation was complete by November 18, 2008. Basic initial training was provided by IDI personnel and the unit was placed into service on November 25, 2008. From the beginning, there were multiple problems with the pilot unit, including issues with the raw wastewater pumping system, lack of a screening system, unit mixers, inadequate unit blowers, and composite samplers. Multiple conference calls were held regarding these issues. On December 3, 2008 process modifications were approved and it was decided that the pilot study must be extended so that a full 6 month evaluation could be completed. The process was immediately seeded and flow was processed through the system. Over the next few weeks, stable growth began to accumulate on the media and the pilot study was officially “started” on December 19, 2008.

The next two months of the pilot study were riddled with questionable equipment operation, system blockages, and increased operator maintenance in order to keep the pilot system operating. Only minimal operational data was collected and system performance and analysis, at this point, was very difficult to evaluate. On February 24, 2009 the pilot unit experienced an overflow, due to a blockage in the line between tank R0 and R1. The main factor for this overflow was the inability to remove hair and debris from the head of the system, which then conglomerated in the lines and eventually blocked the line completely. The pilot unit was cleaned and placed back into service; however additional maintenance was required to prevent future overflows from the system. In addition, elevated dissolved

oxygen levels within the initial anoxic tanks caused problems throughout the remainder of the tanks.

The pilot system operated for approximately another month, with only questionable analytical data and continued questionable equipment operation. At this point, the wastewater temperature was increasing and the operator maintenance required to keep the system running was excessive. On March 12, 2009 the Authority terminated the pilot study and requested IDI to remove the pilot unit from the treatment facility, clean and rebuild the pilot unit and try the study again in September of 2009.

Although the initial pilot study was not successful, a significant amount of valuable information was gathered regarding this type of treatment process, including:

- Staged screening and grit removal is extremely important.
- Influent dissolved oxygen levels, resulting from the screw pumps, are too high to allow the process to work effectively. Therefore, the screw pumps should be replaced with a series of suction lift pumps.
- Proper aeration and mixing are critical to system performance.
- Clarifiers and filters will be required to ensure EBNR levels.
- The Authority waste stream is very well suited for growth on the plastic media.
- Flow equalization will be required to protect the biological treatment process during periods of excessive flow.

## **IMPROVED STUDY**

During the summer of 2009, the staff at IDI completely emptied, cleaned and rebuilt the pilot unit. On August 20, 2009 SMTMA and Glace personnel went to Ashland Virginia to inspect the revisions/upgrades to the pilot unit. Through this inspection, it was determined that the pilot system was constructed much better, including a complete screening system and improved operating and sampling equipment. The unit was authorized to come back to the treatment facility in the beginning of September. On September 9, 2009 the pilot unit was set-up, seeded and operating at the wastewater treatment facility. It was immediately apparent that this pilot unit was much improved over the previous unit.

As with the initial pilot unit, this was a five stage IFAS/MBBR style of system, including the following zones: Pre-anoxic, Anoxic, Aerated (with media), Post anoxic, and

Re-aeration. A complete process schematic is included as Attachment E. Complete analytical data was collected and analyzed throughout the duration of the study; however this discussion will focus primarily on the Total Nitrogen and Total Phosphorus removal capabilities of the process. A compilation of the pilot study data, including biological reduction data and process performance charts, is included as Attachment F. In addition, IDI has provided a Pilot Study report which is not included as part of this study, but is available for review at the Authority office.

The system immediately began to develop substantial biomass on the media within the aeration tank, and the mixed liquor suspended solids within the process continually increased. As a result, the pilot study was officially started on September 24, 2009. The process was allowed to run on its own, without the use of an alternate carbon source, to determine the true capabilities of the process. During the period from September 24 through November 5, the process operated without an alternate carbon source, and averaged the following effluent results:

- TN = 11.91 mg/L
- TP = 2.61 mg/L

The next stage of the pilot study utilized UniCarbDN as an alternate carbon source. UniCarbDN is an attractive alternative to methanol, as it is much safer to handle, and the cost per gallon is very comparable. Initially, the carbon source appeared effective; however the effluent condition rapidly deteriorated, and the results were comparable with no addition of an alternate carbon source. Further investigation revealed that the carbon source was diluted by IDI personnel with plant effluent, which likely contaminated the product and caused the results to be questionable at best. This stage was allowed to run until December 24, 2009, when it was determined that the results were not usable. It is our belief that, if not diluted or diluted properly, the UniCarbDN is capable of being a very effective carbon source; however time would not allow further pilot testing with this chemical. Although the Total Nitrogen reduction was minimal, Total Phosphorous reduction had improved versus operation without an alternate carbon source. The process was allowed to run for a two week period to re-stabilize, and prepare for the next carbon source. During this entire stage the process averaged the following effluent results:

- TN = 10.16 mg/L
- TP = 1.4 mg/L

The next stage of the pilot study utilized MicroCG as an alternate carbon source. MicroCG is a very attractive alternative to methanol, as it is extremely safe to handle and it is a completely “green” chemical. Unfortunately, the cost is approximately 3 times that of methanol on a per gallon basis. From the start, the carbon source was very effective. The process was allowed to run from January 4 through February 8, 2010 with much more impressive results than the UniCarbDN. In addition, the temperatures during this period were in line with some of the coldest temperatures recorded during the past several years. Again, please note the continued improvement in biological Total Phosphorus reduction. During this stage the process averaged the following effluent results:

- TN = 4.31 mg/L
- TP = 0.89 mg/L

The final stage of the pilot study utilized methanol as the alternate carbon source. Methanol is the most readily available and most commonly used carbon source for wastewater treatment plants. Unfortunately it is extremely hazardous to store and handle, requiring specially constructed buildings and complex feed/monitoring systems, all of which increase the capital cost of the project. Feed rates for the methanol are substantially less than MicroCG, and are slightly less than the UniCarbDN, which will result in annual operating cost savings. Initially, the carbon source performance was questionable, mainly due to the time required for the process to acclimate to the new chemical. The process ran from February 9 through March 31, 2010. Again, temperatures during this period were in line with some of the coldest temperatures recorded during the past several years. As with the MicroCG, the Total Nitrogen and Total Phosphorus reduction was very impressive, with the following average effluent results:

- TN = 3.47 mg/L
- TP = 0.90 mg/L

## **CONCLUSION**

Based on the performance and results from the “improved pilot study” it is very apparent that the five stage IFAS/MBBR process, as identified in Section 5, is an acceptable treatment process for the Authority. It was demonstrated, during the coldest months of the year, that both biological Total Nitrogen and Total Phosphorus reduction is substantial

utilizing this process. Please keep in mind that Total Nitrogen reduction will very much depend on the non-biodegradable fraction of nitrogen (the fraction that cannot be removed biologically) which ranged from 2.1 mg/L to as high as 3.1 mg/L during the pilot study.

As mentioned previously, this process will not eliminate the need for new construction. The major benefit of the process is that no new construction is required for biological treatment, as it will utilize all of the existing tankage for biological treatment. New clarifiers and filters are required to ensure desired effluent quality over the next 30 – 40 years. In addition, as was discovered in the “initial pilot study” proper screening and grit removal is extremely critical to the performance and longevity of the process. Also, the ability to eliminate, or at least limit, the dissolved oxygen levels in the initial treatment tanks is vital for optimizing the biological phosphorus removal capabilities of the process. Finally, an equalization tank is required to protect the biological process during periods of excessively high flow.

## **SECTION 7:**

# **NUTRIENT TRADING CREDITS**

Nutrient trading is another approach to improve water quality within the Chesapeake Bay watershed using market mechanisms to produce nutrient reductions without treatment facility upgrades and infrastructure improvements. The nutrient trading program is an option for point and non-point sources that exceed their annual CAP loadings, to purchase credits in an effort to maintain regulatory compliance. Additionally, it is an opportunity for point and non-point sources that provide treatment sufficient to maintain surplus loadings, to generate credits that may be traded or sold to others who are seeking nutrient reduction credits. South Middleton Township Municipal Authority is in a unique position where it may desire to purchase Total Nitrogen credits, while there is the potential to sell Total Phosphorus credits. Both possibilities will be discussed later in this section.

Nutrient trading can occur for either total nitrogen or total phosphorus, in addition to sediment credits. The following identifies some of the basic trading principles of the program.

- ❖ Credits are the unit of compliance that corresponds to a pound of reduction of nutrient or sediment, as recognized by the PA DEP, which can be traded.
- ❖ Credits generated by trading cannot be used to comply with existing technology based effluent limits, except as authorized by federal regulations.
- ❖ Credits must be expressed in a term that corresponds to a unit of compliance (ex. pounds) and a time period; all contained in applicable permit compliance requirements.
- ❖ Credits will be expressed as pounds per year and will be valid for a period of one year, which means that credits need to be measured, verified, and accounted for on a yearly basis. Groups of credits for nutrient reduction will be valid for a period of one year, which corresponds with the “water year” of October 1 to September 30.
- ❖ Credits cannot be banked for future years and must be applied for the year that they are generated or purchased.
- ❖ Trading may occur within the Pennsylvania Portion of the Chesapeake Bay Watershed, specifically within the Susquehanna or Potomac Watersheds. Trading must occur within the same watershed, therefore trading between a source in the Susquehanna watershed and the Potomac watershed is not permitted.

- ❖ Trades must be for comparable credits, such as total nitrogen for total nitrogen.
- ❖ Credits cannot be generated from the purchase and idling of whole or substantial portions of farmland to provide credits for use off site.

When calculating credits, trading ratios need to be considered and used. The types of ratios, including delivery, reserve and edge of segment, will be applied to credit generating activities occurring throughout the Chesapeake Bay Watershed. These ratios affect the number of credits generated and traded and are identified below.

- ❖ Delivery ratio compensates for how nutrients travel within the water. The ratio varies depending on the distance of the source from the mainstream of the Chesapeake Bay. Generally, the greater the distance the pollutant has to travel, the greater the pollutant loss will be. This ratio works to equalize a trade between a source in the headwaters and a source in the mainstream.
- ❖ Reserve ratio is applied to require that part of the credits generated be reserved to cover for failed credit generating activities. This ratio adds another layer of security to the credits. The ratio is ten percent and is applied to all credits.
- ❖ Edge of Segment ratio is a factor that is unique to each individual watershed to estimate the loadings credits for non-point sources.

In regards to nutrient trading, South Middleton Township Municipal Authority will be focused mainly on the purchase of total nitrogen credits; however, there is potential to sell total phosphorus credits for a period of five to ten years. Discussion will start with Total Phosphorus credit generation, and Total Nitrogen purchasing will be discussed later in the report.

The Authority will ultimately have a CAP loading of 3,652 pounds per year for Total Phosphorus. The treatment facility currently generates 330 pounds per year, and it is estimated that with the existing treatment process, as well as either of the recommended biological treatment processes, that an initial average of 330 pounds per year will be generated. This number will increase and continue to increase, as additional housing units are added to the collection system and annual average flows increase. Attachment G “Nutrient Trading Worksheet” identifies the projected Total Phosphorus loadings until 2030. It is estimated that 180 EDU’s will be added yearly, with approximately 0.12

lbs/day/EDU being generated. Attachment G also identifies the projected number of credits generated yearly. The current market price for Total Phosphorus credits, as provided through Red Barn Trading Company, is \$4.00 per credit. Based on discussions with PA DEP, as well as Red Barn Trading Company, it is reasonable to estimate that the future prices will be as follows:

- ❖ \$4.50 per credit from 2015 through 2020
- ❖ \$5.00 per credit from 2021 through 2025
- ❖ \$5.50 per credit from 2026 through 2030

It is projected that with annual average flows of 1.516 MGD, annual Total Phosphorus loadings of 999 pounds will be generated. The Authority is projected to generate the following credits:

- ❖ 19,219 credits from 2010 through 2015
- ❖ 15,422 credits from 2016 through 2020
- ❖ 14,882 credits from 2021 through 2025
- ❖ 14,342 credits from 2026 through 2030

Attachment G incorporates a safety factor of 15 percent to allow for reserve loadings, and this practice is strongly recommended. Revenue generated through Total Phosphorus credits is estimated as follows:

- ❖ \$65,345 from 2010 through 2015
- ❖ \$58,989 from 2016 through 2020
- ❖ \$63,249 from 2021 through 2025
- ❖ \$67,049 from 2026 through 2030

This will provide estimated total revenue of \$254,632 over the next twenty years. For this reason, it recommended that the Authority pursue trading their generated Total Phosphorus credits. Attachment G “Nutrient Trading Worksheet” provides a complete analysis of this option.

The Authority will have a CAP loading of 27,396 pounds per year of Total Nitrogen. The treatment facility currently generates an average of 48,218 pounds per year at an annual average flow of 0.580 MGD, requiring the purchase of 20,821 credits. Attachment G, Nutrient Trading Worksheet, identifies the projected Total Nitrogen loadings until 2030. It is estimated that 180 EDU’s will be added yearly, with approximately 9 lbs/day/EDU being generated. Attachment F also identifies the projected number of credits required yearly. It

is estimated that the existing treatment process will generate approximately 82,257 pounds per year at a capacity of 1.516 MGD, requiring the purchase of 54,861 credits. The current market price per credit for Total Nitrogen credits, as provided through Red Barn Trading Company, is as follows:

- ❖ \$5.15 from 2010 through 2015
- ❖ \$6.71 from 2016 through 2020
- ❖ \$7.98 from 2021 through 2025
- ❖ \$9.01 from 2026 through 2030

The Authority is projected to require purchase of the following Total Nitrogen credits over the next twenty years:

- ❖ 178,392 credits from 2010 through 2015
- ❖ 193,210 credits from 2016 through 2020
- ❖ 233,710 credits from 2021 through 2025
- ❖ 274,210 credits from 2026 through 2030

Funding required to purchase the necessary Total Nitrogen credits is as follows:

- ❖ \$918,719 from 2010 through 2015
- ❖ \$1,296,439 from 2016 through 2020
- ❖ \$1,865,006 from 2021 through 2025
- ❖ \$2,470,632 from 2026 through 2030

This provides a total projected cost of \$6,550,796 over the next twenty years. Amortization for this option, assuming 4.00% for a period of twenty years, is \$527,574.

**Purchase of the required Total Nitrogen credits is not recommended for the following reasons:**

- ❖ This option provides no protection to the receiving water of the Yellow Breeches
- ❖ The treatment facility will require upgrades anyway, due to age and condition
- ❖ Biosolids storage and handling facilities will still need to be constructed to accommodate the increased capacity of the treatment plant.

**It is recommended that the Authority investigate selling nitrogen credits after the project has been completed. It is anticipated that approximately 10,224 credits could be generated annually, resulting in approximately \$53,000 of income per year.**

**SECTION 8:**

**EVALUATION OF PRELIMINARY  
AND TERTIARY TREATMENT  
ALTERNATIVES**

The following section identifies and briefly discusses the available preliminary and tertiary treatment alternatives, including screening systems, grit removal systems, final clarifiers, tertiary filters, and disinfection systems. Each of these treatment processes is vital to maintaining optimum performance and regulatory compliance for the entire facility.

## **A) PRELIMINARY TREATMENT**

Preliminary treatment processes generally consist of screening and grit removal units. These units are designed to separate and remove heavy coarse material from the wastewater to be treated. Wastewater flowing into treatment facilities contains paper products, rags, grit, and occasionally pieces of wood, roots, plastic, and other large debris. To protect process equipment, and reduce interference with the downstream treatment processes, these materials must be removed from the waste stream. As demonstrated through the IFAS/MBBR pilot study, these processes are very critical to optimized biological treatment.

### **SCREENING UNITS**

Screening units are the first process in the removal of these materials. In the past, most influent screen units consisted of parallel bars placed at an angle within the flow channel, such that the wastewater would pass through the bars and the larger debris and materials would be contained on the bars. These bar screens were typically manually cleaned, however mechanical cleaning was also available. The standard bar spacing was generally 1" to 2", which allowed for paper products and rags to pass through and enter the treatment process. As biological treatment technology advanced, it became critical for these units to be completely automated allowing more operator time to monitor the treatment process, and for the units to remove the smaller paper products and rags. Additionally, it is important that the materials removed be washed, compacted, and dewatered, because the screenings will contain soluble BOD which must be returned back to the waste stream for the downstream biological process. Further more, compaction and dewatering helps to return even more soluble BOD, while reducing the weight of the solids sent to the landfill, thus saving money. For South Middleton Township Municipal Authority, we are recommending staged screening units with a 3/4" course screen, followed by fine screening at 1/8" (3mm) spacing, as well as washing, compacting, and dewatering capabilities. These key features are necessary for the IFAS/MBBR system. The 1/8" (3mm) bar spacing will remove the debris that can cause serious problems within the treatment processes, such as plugging of the pumps and diffusers and blinding of the analytical probes. The washing,

compacting, and dewatering feature will return the necessary soluble BOD to the wastestream. This BOD is critical to the effective and efficient operation of both of the proposed treatment systems.

There are dozens of mechanical screens available on the market with varying types of operation, materials of construction, energy requirements, and maintenance requirements. Table 8.1 below identifies three recommended screen units, including estimated equipment, annual energy, and construction costs.

**Table 8.1**

<b>Screen Unit</b>	<b>Est. Equipment Cost *</b>	<b>Est. Construction Cost</b>	<b>Estimated Annual Energy Cost</b>	<b>Estimated Annual Cost **</b>
<b>Lakeside Raptor Fine Screen</b>	<b>\$185,000</b>	<b>\$235,000</b>	<b>\$2,500</b>	<b>\$34,996</b>
<b>Duperon Flexrake Screen System</b>	<b>\$145,000</b>	<b>\$215,000</b>	<b>\$2,100</b>	<b>\$28,596</b>
<b>Hydro-Dyne Wiese-Flo Screen</b>	<b>\$162,000</b>	<b>\$232,000</b>	<b>\$2,600</b>	<b>\$31,598</b>

**\*Based on 2010 Dollars**

**\*\* 20 Years @ 4.00%, Including O&M Costs**

The above identified screens are recommended for the following reasons:

- a) All are constructed of stainless materials for corrosion resistance.
- b) No drive parts (bearings, etc.) are submerged within the flow channel.
- c) All provide convenient access for lubrication and scheduled maintenance.
- d) All operate through energy efficient motors and controls to reduce energy, operating, and maintenance costs.

### **GRIT REMOVAL UNITS**

Grit must be removed early in the treatment process because it is extremely abrasive and will rapidly wear out pumps and other process equipment and settle in the treatment tanks rendering the space occupied by the grit useless, effectively reducing the capacity of the tanks. Since it is mostly inorganic, it cannot be broken down by any biological processes,

and therefore should be removed before the primary treatment units. If the grit is not removed, it will settle out within the biological treatment basins, interfering with the biological treatment process and causing the basins to be manually cleaned more frequently.

Grit can be removed several ways. A typical process involves the construction of a long narrow channel, called a grit channel, where the velocity of the wastestream is reduced to one foot per second (fps), allowing the larger heavier grit particles to settle out, where it is then either manually or mechanically removed. In most cases, these channels are aerated, using compressed air and diffusers within the channel, to provide better separation of the grit materials and “freshen” the wastewater to prevent odors and assist the downstream biological process. This type of grit removal system is not recommended for South Middleton Township Municipal Authority for the following reasons:

- a) A large area is required for the construction of the grit channels.
- b) Grit channels require significant maintenance, especially when cleaning is required.
- c) Additional air system and mechanical cleaning system provide additional maintenance and operating costs.

A second option for grit removal is vortex separation. Through this process the waste stream is directed to the treatment unit where it is forced into a spiral vortex. The flow velocity is maintained at approximately one foot per second within the vortex chamber, keeping organics in suspension while allowing the heavier grit to settle to the chamber floor. The settled grit is then moved across the chamber floor towards a center opening and into a grit hopper. Grit is removed from the hopper by either an air-lift or self-priming pump and sent to a grit classifier for washing, compaction and dewatering, similar to the screened materials. It will then be discharged to a waste dumpster and then eventually to the sanitary land fill. Most units of this nature are capable of removing up to 95% of all grit particles from the waste stream. This process is recommended for South Middleton Township Municipal Authority for the following reasons:

- a) Compact design, requires minimal area.
- b) Minimal cleaning is required..
- c) Minimal external power is required.
- d) Minimal maintenance is required.

For South Middleton Township Municipal Authority we are recommending two possible grit removal units, both of which are vortex type units, as described above. Table 8.2 identifies the recommended grit removal units, including estimated equipment, annual energy, and construction costs.

**Table 8.2**

<b>Grit Removal Unit</b>	<b>Est. Equipment Cost *</b>	<b>Est. Construction Cost</b>	<b>Estimated Annual Energy Cost</b>	<b>Estimated Annual Cost **</b>
<b>Hydro-International Grit King</b>	<b>\$280,000</b>	<b>\$200,000</b>	<b>\$550</b>	<b>\$37,558</b>
<b>Lakeside Aeroductor Grit System</b>	<b>\$161,000</b>	<b>\$300,000</b>	<b>\$1,200</b>	<b>\$35,129</b>

**\*Based on 2010 Dollars**

**\*\* 20 Years @ 4.00%, Including O&M Costs**

## **B) TERTIARY TREATMENT/DISINFECTION**

Tertiary treatment generally consists of final clarifiers and tertiary filters with disinfection systems. The units are designed to provide final treatment of the waste stream before discharge into the receiving stream. Effective operation of these units is critical to achieving and maintaining compliance with the current and future National Pollutant Discharge Elimination System limitations for the wastewater treatment facility

### **FINAL CLARIFIERS**

The recommended wastewater treatment process, IFAS/MBBR, will produce activated sludge that contain large populations of micro-organisms and associated flock material that must be removed before the effluent can be discharged to the receiving stream. This removal process is best accomplished by the final clarifiers. Within the final clarifiers, the heavier materials separate and settle to the bottom of the tank, while the clear effluent passes from the tank to the downstream processes. The settled sludge is generally transferred along the bottom of the tank by a series of scraper arms to a sludge hopper. From this hopper, the sludge is either returned to the appropriate biological reactor or

pumped into the digesters for stabilization, volatile solids reduction, and production of a reusable end product.

The final clarifier is one of the critical processes within the entire treatment facility. The final clarifier must perform two functions, clarification and thickening. Clarification is the separation of solids from the liquid stream to produce clarified effluent with low levels of suspended solids in the effluent. Thickening is the compaction of sludge particles at the bottom of the tank, resulting in a slightly concentrated underflow, or return activated sludge. Several factors influence the performance of final clarifiers including: clarifier area, placement of the baffles to promote quiescent settling and equal distribution of the mixed liquor suspended solids, design of sludge removal equipment, mixed liquor suspended solids concentrations, and sludge settleability. In general, mixed liquor suspended solids concentrations of 3,000 to 5,000 mg/L provide favorable sludge for final clarification. The IFAS/MBBR system processes produce effluent with mixed liquor suspended solids concentrations within the desired range. Additionally, both processes produce high quality sludge that separates and settles efficiently within the final clarifiers.

For the South Middleton Township Municipal Authority, we are recommending the construction and installation of two circular clarifier units, approximately 55' in diameter. These units will replace the existing settling tanks that will be modified and made part of the biological treatment process, as discussed earlier in the report. Exact location of the clarifiers is dependent upon the type of biological treatment process selected, however the clarifiers can be placed within the existing fenced area, as identified in Attachment D Conceptual Process Layout. Table 8.3 identifies the recommended final clarifier units, including estimated equipment, annual energy and construction costs.

**Table 8.3**

<b>Final Clarifier Units (2)</b>	<b>Est. Equipment Cost *</b>	<b>Est. Construction Cost</b>	<b>Estimated Annual Energy Cost</b>	<b>Estimated Annual Cost **</b>
<b>EIMCO Model C-3</b>	<b>\$211,000</b>	<b>\$275,000</b>	<b>\$750</b>	<b>\$36,519</b>
<b>Siemens “Tow- Bro” System</b>	<b>\$270,000</b>	<b>\$285,000</b>	<b>\$700</b>	<b>\$39,850</b>
<b>Kruger</b>	<b>\$258,000</b>	<b>\$285,000</b>	<b>\$700</b>	<b>\$40,664</b>

\*Based on 2010 Dollars

\*\* 20 Years @ 4.00%, Including O&M Costs

### TERTIARY FILTERS

Tertiary filtration is a process designed to remove trace suspended solids and the resulting BOD from the effluent of the final clarifiers.

Two main types of tertiary filtration include disc filters and deep bed filters. Disc filters employ cloth filter elements installed vertically on multiple discs, resulting in a large filtering surface area within a small footprint. In general, disc filters are as much as 50% smaller than deep bed filters. Additionally, disc filters operate with a minimal number of mechanical components. Deep bed filters utilize sand and multiple types of granular media to provide the necessary filtration. The wastewater flows downward through the gaps between the media, which restricts the solids and retains them on and within the media. When significant headlosses are reached, the filter is mechanically backwashed and the removed wastewater solids are transferred to the head of the plant. Both types of tertiary filter systems are standard with automatic controls and automatic backwash cycles.

For many years, the installation of tertiary filters was limited; however, the Chesapeake Bay Tributary Strategy requirements for biological nutrient removal have resulted in an increase in the application of this process. In the case of South Middleton Township Municipal Authority, the need for enhanced biological nutrient removal to achieve the effluent limitations established with a predicted total capacity of 1.5 MGD has made the installation of this process mandatory. As discussed previously, tertiary filtration will be required with the IFAS/MBBR process, as the current technology of this process will not

guarantee the enhanced biological nutrient removal effluent concentrations of nitrogen and phosphorus when the facility is operating at design flow capacity. Based on removal capabilities, tertiary filtration will be required when the annual average flow at the treatment facility has reached 1.0 MGD. The location of the tertiary filters is dependent upon the biological treatment process selected, however the filters can be placed within the existing fenced area of the treatment facility, possibly within the existing filter building, as identified in Attachment D Conceptual Process Layout. Table 8.4 identifies the recommended tertiary filter units, including estimated equipment, annual energy, and construction costs.

**Table 8.4**

<b>Tertiary Filtration Unit</b>	<b>Est. Equipment Cost *</b>	<b>Est. Construction Cost</b>	<b>Estimated Annual Energy Cost</b>	<b>Estimated Annual Cost **</b>
<b>Kruger/Hydrotech Discfilter</b>	<b>\$494,300</b>	<b>\$300,000</b>	<b>\$1,350</b>	<b>\$59,788</b>
<b>Ashbrook</b>	<b>\$395,000</b>	<b>\$290,000</b>	<b>\$1,000</b>	<b>\$48,280</b>

**\*Based on 2010 Dollars**

**\*\* 20 Years @ 4.00%, Including O&M Costs**

## **DISINFECTION SYSTEMS**

Although the biological treatment, clarification, and filtration processes remove a great number of organisms from the wastewater, still millions of bacteria remain in every gallon of water leaving these processes. It is quite possible that many of the bacteria are pathogenic, or harmful to humans and aquatic life, therefore, the effluent stream must be disinfected. Disinfection is generally defined as a process designed to kill or inactivate pathogenic organisms. Disinfection can be accomplished through many processes such as chlorine gas, sodium hypochlorite, and ozone; however ultra-violet disinfection has been identified as the optimum type of disinfection for South Middleton Township Municipal Authority for the following reasons:

- a) De-chlorination is not required.
- b) Chemical handling, storage, and containment is not required.
- c) Minimal training of personnel is required.

- d) UV disinfection systems are easier to operate and maintain than chlorine gas, sodium hypochlorite and ozone.
- e) UV disinfection systems are intrinsically safer for plant operational personnel.

Just beyond the visible light spectrum there is a band of electromagnetic radiation, which is referred to as ultraviolet (UV) light. When ultraviolet radiation is absorbed by the cells of micro-organisms, it damages the genetic material in such a way that the micro-organism is no longer able to grow or reproduce, ultimately killing it. This ability to disinfect using UV radiation has been around for nearly a century; however technological advances have now brought the process to a point where it can effectively, efficiently, and reliably provide the required disinfection for wastewater treatment facilities. The general source of the UV radiation for disinfection systems is from low pressure mercury vapor UV lamps which have been designed into multi-lamp systems. Each lamp is protected by a quartz sleeve and has watertight connections. Most applications place the assembly within the flow channel and allow the flow to pass through the lamp assemblies, however one of the systems we will recommend places the lamp assemblies outside of the flow channel, allowing the flow to pass through translucent tubes surrounded by the lamp assemblies, which allows the bulbs to be serviced and maintained more easily.

For the South Middleton Township Municipal Authority, we are recommending three UV disinfection systems, two are placed within the flow channel and one is placed outside of the flow channel. The Wedeco and Aquaray systems place the UV bulbs directly into the effluent flow channel. The Enaqua system allows the effluent flow to pass through translucent tubes which are surrounded by the UV bulbs, therefore the UV bulbs are in a dry, climate controlled location, thereby increasing the life of the bulbs and simplifying standard maintenance. It is recommended that a pilot study be conducted using the Enaqua system, as this is the most cost effective option.

Location of the disinfection system depends upon the biological process selected; however, it may be possible for the unit to be placed within the existing filter building. In either case, the unit can be placed within the existing fence, as identified in Attachment D “Conceptual Process Layout”. Table 8.5 below identifies the recommended UV disinfection systems, including estimated equipment costs, estimated annual energy costs, and estimated construction costs.

**Table 8.5**

<b>UV Disinfection System</b>	<b>Est. Equipment Cost *</b>	<b>Est. Construction Cost</b>	<b>Estimated Annual Energy Cost</b>	<b>Estimated Annual Cost **</b>
<b>Enaqua System</b>	<b>\$190,000</b>	<b>\$205,000</b>	<b>\$650</b>	<b>\$29,834</b>
<b>Wedeco</b>	<b>\$175,000</b>	<b>\$215,000</b>	<b>\$800</b>	<b>\$28,014</b>
<b>Aquaray 40 HO</b>	<b>\$185,000</b>	<b>\$215,000</b>	<b>\$950</b>	<b>\$30,390</b>

**\*Based on 2010 Dollars**

**\*\* 20 Years @ 4.00%, Including O&M Costs**

## **SECTION 9:**

# **BIOSOLIDS HANDLING AND PROCESSING**

Biosolids handling and processing is a critical step in the overall treatment process that requires investigation of the following areas: recycle streams, biosolids production, biosolids digestion, current biosolids disposal capabilities, and future biosolids disposal possibilities.

### **A) RECYCLE STREAMS**

The biosolids wasted from an enhanced biological nutrient removal (EBNR) process will contain approximately 8% to 10% phosphorus and 12% to 14% nitrogen on a dry weight basis. Consequently, these biosolids need to be handled and processed with caution to ensure that the recycle streams do not overload the mainstream process, causing operational upsets, and potential non-compliance issues. Recycle streams from the existing reed beds and return of decanted material from the digesters, as well as return flows from thickening and de-watering equipment, will need to be designed carefully to ensure that high concentrations of nitrogen, phosphorus and total suspended solids are not returned to the main waste stream. It is recommended that these recycle streams be designed to flow into the equalization tank, and then released to the raw pumping station at an operator controlled rate to prevent overloading of the biological treatment process.

### **B) BIOSOLIDS PRODUCTION**

EBNR processes will generally result in an 8% to 10% increase in biosolids production. The increase in biosolids production is dependent upon the mixed liquor suspended solids maintained within the treatment basins as well as the sludge retention time of the process selected. Tables 9.1, and 9.2 provide a comparison of the anticipated biosolids production for the current treatment process and the Integrated Fixed Film Activated Sludge/Moving Bed Biological Reactor Process.

**Table 9.1**

**Existing Extended Aeration Process**

<b>ANNUAL AVERAGE FLOW (MGD)</b>	<b>MIXED LIQUOR SUSPENDED SOLIDS (MG/L)</b>	<b>SLUDGE RETENTION TIME (DAYS)</b>	<b>ESTIMATED BIOSOLIDS WASTING (GPD)</b>
0.560	3,650	8	8,250
0.750	3,650	8	8,700
1.00	3,650	8	9,150
1.25	3,650	8	9,600
1.50	3,650	8	10,075

**Table 9.2**

**IFAS / MBBR**

<b>ANNUAL AVERAGE FLOW (MGD)</b>	<b>MIXED LIQUOR SUSPENDED SOLIDS (MG/L)</b>	<b>SLUDGE RETENTION TIME (DAYS)</b>	<b>ESTIMATED BIOSOLIDS WASTING (GPD)</b>
0.560	4,500	6	8,663
0.750	4,500	6	9,435
1.00	4,500	6	9,907
1.25	4,500	6	10,480
1.50	4,500	6	11,178

The existing digesters and current reed beds will be able to accommodate daily wasting of approximately 9,500 gallons per day. As demonstrated by the tables above, biosolids wasting and sludge production will increase past the current capabilities of these processes. For this reason, it is critical for the Authority to prepare for the increased sludge production generated by the EBNR processes.

**C) BIOSOLIDS DIGESTION**

Solids wasted from the IFAS/MBBR process are extremely aerated throughout the entire process. For this reason, it is recommended to continue utilizing aerobic digesters, as is the case with the existing facility. Separate aerobic digesters are required to ensure that residual solids from the biological treatment process are digested to the fullest extent

possible. Aerobic digestion is a separate operation from the biological treatment process. Its purpose is to extend decomposition of solids and re-growth of organisms to a point where available energy in active cells and storage of waste materials are low enough and the material is stable enough for ultimate disposal. Aerobic digestion tanks can be either round or rectangular, with general depths between 15 and 20 feet. The tanks incorporate aeration equipment (mechanical or diffused air) to maintain aerobic conditions.

The existing treatment process uses two aerobic digesters within the initial “train”, each with a volume of 53,856 gallons, as well as two aerobic digesters within the newer train, each with a volume of 78,450 gallons. This provides a total of four aerobic digesters with a total capacity of 264,792 gallons. Unfortunately, the sizing and placement of the current digester tanks makes them undesirable to be maintained as digesters within the new treatment process. As a result, the existing digester tanks will be better utilized incorporated into the new treatment process, as part of the post-anoxic zone within either of the treatment processes, as described in Section 5. Therefore, new digesters will need to be constructed as part of the treatment process upgrade. Based on the above tables and the estimated biosolids wasting for each of the treatment processes, it is recommended that the Authority initially construct a series of six digester basins, using common wall construction to minimize costs, each with a capacity of 120,000 gallons. This will provide an initial capacity of 720,000 gallons, which represents an increase of approximately 74% over the existing facilities. It is also recommended that once the treatment facility reaches an annual average flow of 1.5 MGD, two additional 120,000 gallon digesters be designed and constructed. Location of the aerobic digesters is recommended near the administrative building and steel storage building, to allow space near the treatment plant for required construction of clarifiers, filters and UV disinfection facilities. This potential location is identified in Attachment D “Conceptual Process Layout”.

## **D) CURRENT BIOSOLIDS DISPOSAL CAPABILITIES**

### **REED BEDS**

Sludge processing is currently accomplished through thirteen reed beds located along Lear Lane, across the street from the administrative offices. Reed beds are essentially constructed wetlands that use a common reed, *Phragmites australis*, as their treatment facilitator. In typical activated sludge applications, reed beds can reduce water content by approximately 40%. This is accomplished through the combined actions of percolation,

surface evaporation, and most significantly leaf evapo-transpiration. Additionally, the development of a stable micro-flora in the root zone helps to break down the biosolids into water and carbon dioxide, with a corresponding reduction in volume.

Initially, the reed beds will be moderately successful in breaking down and consuming the wasted nitrogen and phosphorus, however as the annual average flow increases, the phosphorus and nitrogen loading to the reed beds will also be increased, making it more difficult to break down and consume these nutrients, therefore the recycle to the main waste stream will likely need to be treated. The existing thirteen reed beds will be able to process biosolids until the annual average flow exceeds 0.750 MGD. At this point, biosolids production will have increased to a point where it cannot be treated by the reed beds alone, therefore additional treatment processes will need to be constructed.

### **AGRICULTURAL UTILIZATION**

In addition to the reed beds, the Authority has started a land application program for additional biosolid disposal capabilities. The Authority has started land applying biosolids to the Wickard Farm, located approximately ½ mile from the treatment facility and administrative offices.

Aerobically digested sludge can be applied to the land, mainly on farm fields, and used as a fertilizer and soil conditioner. Sludge can be applied either directly from the digesters (wet), or after mechanical dewatering processes (cake). In the case of applying wet, sludge must be either stored in the digesters or transferred directly from the digesters into above ground holding tanks for storage until ground and soil conditions allow for sludge application. It is critical that the digesters and/or holding tanks be sized properly to compensate for the winter and early spring months when field conditions are not conducive to sludge application, which is why we are recommending initial digester volumes of 720,000 gallons, with expansion to 980,000 gallons at annual average flows of 1.5 MGD. In the case of applying de-watered materials, the sludge is drawn from the digesters, and mechanically de-watered, as will be discussed later in the report. After the sludge is de-watered, it is transferred to a covered storage area, until ground and soil conditions allow for application. This is a valuable method of sludge disposal, if available, as it returns nutrients back to the land, thus completing the natural cycle for most nutrients.

Transporting the sludge to the disposal site (fields) is generally accomplished by tanker trucks or direct pipelines. The application of sludge depends upon the topography of

the land and the crops to be raised. When applied to grass and low ground cover crops, application will incorporate spraying from the back of the tanker truck while driving over the land. Another less acceptable method, but the most costly, includes leveling the land, constructing ridges and furrows, and then pumping the sludge down the furrows similar to irrigation practices. This method is capable of reclaiming land previously unsuitable for tree and plant growth, and may potentially yield crops equal to or greater than those raised with commercial fertilizers.

Agricultural utilization is an attractive process for many treatment facilities. As mentioned previously, South Middleton Township Municipal Authority has permitted approximately 80 acres of farm land for agricultural utilization. We recommend additional farmland of not less than 80 acres for future disposal requirements, as this will allow for proper crop rotation practices to be established and maintained, while allowing for sufficient disposal of sludge. The additional farm land and fields will need to be permitted through the Pennsylvania Department of Environmental Protection and approved by the Cumberland County Conservation District, with annual sampling and analytical reporting to PADEP.

The following items are strongly recommended with this option:

- ❖ The property should be located as close to the treatment facility as possible, thus limiting the travel distance and the need for additional tanker trucks and equipment.
- ❖ Agreements between the Authority, the property owner and the farmer be prepared to identify the responsibilities, rights and obligations of each party

## **E) FUTURE BIOSOLIDS DISPOSAL POSSIBILITIES**

For the Authority, the existing reed beds and farm fields will not be sufficient enough to meet the total biosolids disposal requirements of the enhanced BNR treatment facility. Additional thickening and/or de-water facilities are recommended to provide multiple options for biosolids disposal. Numerous technologies are available for biosolids processing, including:

- ❖ sludge drying beds
- ❖ sludge lagoons
- ❖ mechanical thickening & de-watering
- ❖ incineration
- ❖ composting and vermi-composting.

❖ landfill

Each of these processes has distinct advantages and disadvantages, however we are recommending mechanical thickening and de-watering as the best approach for the Authority, and will be focused on. The other options will be discussed briefly, for informational purposes only.

### **SLUDGE DRYING BEDS**

The sludge drying process is accomplished through percolation and evaporation of the water from the sludge after it has been deposited on a drying bed. The drying beds are constructed with an under-drain system covered with coarse or crushed rock. On top of the rock is a layer of gravel, and then a layer of pea gravel covered with 6 to 8 inches of sand. Sludge is drawn from the bottom of the aerobic digesters after the digesters have set quiescently for a period of time to allow for thickening of the biosolids, and applied to the drying bed to create a layer 12 to 18 inches thick. In warm weather, sand beds will dry the sludge enough for removal within 4 to 5 weeks, as the water evaporates from the top of the sludge and drains down through the sand/gravel layers. When the sludge has formed cracks that extend to the sand layer, it is ready for removal. In cold weather, the drying time increases significantly as evaporation decreases and freezing of the sludge significantly increases the time required for the clear liquid to drain through the sand and gravel bed.

A major disadvantage of drying beds is that heavy equipment, such as skid loaders and backhoes, cannot be used, as they will severely damage the underdrain system and remove sand from the beds during each removal. Removal of the dried sludge must be performed manually, with pitch forks, which is extremely labor intensive. Additionally, drying beds require a large area for construction, which is not readily available within the existing property. Finally, cold weather severely decreases the efficiency of the drying beds. For these reasons, sludge drying beds are not recommended.

### **SLUDGE LAGOONS**

Sludge lagoons are deep ponds constructed to hold digested solids and supernatant from the digesters. Digested sludge is discharged to the lagoons periodically, until the lagoon is full, which may take as long a year or two if the lagoons are sized appropriately. When the lagoon is full, sludge is discharged to a second lagoon, allowing the first lagoon to dry, which may also take as long as two years. When the material in the lagoon is completely

dried, it must be removed with heavy equipment, such as a backhoe, and transferred to farm fields or sanitary landfills for ultimate disposal.

Properly sized sludge lagoons require a significant amount of area in order to be properly sized and constructed. Additionally, the process can be extremely labor intensive during the sludge removal process, and requires the purchase or rental of expensive heavy equipment for sludge removal. Unfortunately, the necessary land for this type of process is not available, and the labor costs combined with the equipment costs make this process undesirable. For these reasons, sludge lagoons are not recommended.

## **INCINERATION**

Incineration is the burning (combustion) of sludge at high temperature in a furnace. Incineration reduces the volume of sludge, while producing heat, dry inorganic ash, and gaseous emissions. Incineration temperatures can reach as high as 500 degrees Fahrenheit, and the sludge must be physically handled both while loading the incinerator and while removing the organic ash. After the incineration process, the organic ash material can be disposed of in a sanitary landfill.

The state and federal regulations for incineration deal mainly with the gaseous emissions. The largest concern is the fate of metals and certain organics as they pass through the incineration process and are either destroyed, removed with the ash or pass through the gaseous emission scrubbing equipment and exit with the exhaust gases. Scrubbing equipment removes the particulates and undesirable gases from the gaseous emissions by passing the dirty air through water sprays. This resulting concentrated waste stream is returned to the process, creating the potential for process upset, therefore the waste stream may need to be treated separately.

This process is not recommended as a viable alternative for the following reasons:

- ❖ the initial equipment costs including the incinerator, scrubbing equipment, and heavy machinery required to move the sludge will exceed \$1,500,000
- ❖ extensive air quality monitoring and process waste monitoring is required
- ❖ extensive operator attention is required to properly and efficiently operate the system
- ❖ the process is not as reliable as the other alternatives discussed within this report.

## COMPOSTING AND VERMI-COMPOSTING

As these technologies continue to advance, biosolids composting and vermi-composting are becoming more prominent alternatives for biosolids disposal. The initial step for this process is de-watering, through either belt filter presses or centrifuge units. It is recommended that centrifuge units be used, as they provide a drier cake which is more beneficial for use with the composting and more compatible with vermin-composting. In general, a cake of approximately 30% solids is recommended for these composting processes.

### A) GENERAL COMPOSTING

General composting is a process whereby de-watered sludge is mixed with natural organic materials and allowed to decompose naturally; creating a product that can be used by the general public. After de-watering, the cake is transferred to a mixing facility where it will begin the composting process. In the mixing building, the cake is mixed with wood chips and continuously blended to make the compost mix. After the mixture has been sufficiently blended and mixed, it is removed and transferred to an aeration pad, where large blowers draw air through a perforated pipe underlaying each row of compost material. The recycled air must be vented through a biofilter to control the odors and freshen the air. As the mixture remains on the aeration pad, high temperatures are generated within the compost mixture, which release moisture, kill pathogens and decompose organic matter. After the aeration stage, which generally lasts about a month, the compost is transferred to the curing area where it is placed in windrows for curing, providing time for additional decomposition. After the curing process, which also lasts about a month, the compost is moved to the drying area, where it is again aerated to complete the drying and maturation of the compost before screening. The final step in the process is screening. Generally, rotary screens are used to separate the woodchips added in the beginning of the process. The wood chips can be reused, and the stabilized compost material is transferred into storage. Storage of the stabilized compost material includes spreading the material out into windrows, and covering with rubber tarps. The compost is considered a Class A biosolid, and can be used by the public for general fertilizer.

General composting is an advantageous option as it creates a product that can be re-used, rather than being placed into local sanitary landfills. With that said, the process requires a substantial amount of available land to construct the mixing building, the aeration

pad, the curing pad, the screening building, and the storage area. Estimated construction and equipment costs for this are approximately \$1,400,000. Additionally, the process requires substantial operator attention, and in the Authority's case, approximately one additional employee would be needed to efficiently operate and maintain the process. This process would most likely be successful with cooperation from the Township, as the end product would be provided and available for Township residents.

## **B) VERMI-COMPOSTING**

Vermi-composting is a process where earth worms are introduced into de-watered sludge, and allowed to process the de-watered sludge. Vermicompost is the end product of the breakdown of the organic material by the earthworms. It is generally rich in nutrients, and can be used as a natural fertilizer and soil conditioner.

The earthworm species most often used are Red Wigglers or Red Earthworms. Together with bacteria already present in the sludge, the earthworms are the major catalyst for decomposition, since they eat the sludge and discharge castings, rendering the sludge useful.

There are two main methods for large scale vermiculture. The first incorporates placing the de-watered sludge into windrows for the earthworms to live in, and then sludge is added on a timed basis to this windrow. Although the windrow has no physical barriers to prevent the worms from escaping, the belief is that they will not due to an abundance of organic material for them to feed on. Often windrows are used on a concrete surface to prevent predators from killing the worm population. It is vital for these windrows to be covered to prevent weather conditions such as rain and snow from affecting the process.

The second, and most common, type of large scale vermi-composting system is the raised bed flow through system. Here the worms are fed a pre-determined amount of biosolids across the top of the bed, and a pre-determined amount of castings are harvested from below by pulling a breaker bar across the large mesh screen which forms the base of the bed. Because red worms are surface dwellers and are constantly moving toward the new food source, the flow through system eliminates the need to separate the worms from the castings before final packaging. Flow through the systems also needs to be located indoors to protect them from the weather conditions.

Vermi-composting is not recommended as a possible method. The initial construction and equipment costs are estimated to be \$980,000, which is less than general

composting, however the operational requirements are very substantial. In the Authority's case, it is estimated that 2 additional employees would be needed to effectively operate and maintain the system. Additionally, the worms are very sensitive to the pH, alkalinity, nitrogen and phosphorus levels in the sludge, and are easily killed by overloading. Replacement of the worm population for a system is approximately \$10,000 to \$12,000. Finally, the public perception has not yet evolved to a point where the castings are widely accepted as a fertilizer and soil conditioner, therefore large volumes of material are often shipped away for disposal at other locations.

## **LANDFILL**

Disposal of biosolids through landfills is a potential option; however, several things must be considered. To begin, the biosolids must be mechanically de-watered to increase the solids concentration and decrease the total weight of the materials, then stored until it can be hauled to the landfill. This requires the purchase of de-watering equipment and construction of appropriate processing and storage buildings. Next, large equipment is necessary to move the biosolids and haul them to the landfill. In general, this equipment can cost as much as \$350,000. Finally, while biosolids are currently accepted at most landfills within the area, the testing requirements are becoming more stringent and the disposal and tipping fees are continually increasing. It is recommended that disposal through landfills be utilized only if the reed beds and agricultural utilization are not available. It is more environmentally friendly to recycle the biosolids through agricultural utilization or composting, than to dispose of these materials within a landfill.

## **MECHANICAL THICKENING & DE-WATERING**

Based on the type and amount of biosolids generated from the enhanced BNR treatment process, mechanical thickening and de-watering is recommended.

In plants such as the Authority's, where large volumes of sludge will be handled and the reed beds and farm fields are at capacity, mechanical thickening and de-watering is a favorable option. Mechanical thickening and de-watering methods available include rotary drum thickening, screw presses, centrifugation and filter presses. Each of these processes is capable of reducing the moisture content of sludge, leaving a wet, pasty cake containing 6 to 30 percent solids. The cake can then be disposed of in a sanitary landfill, or treated further to become a class A biosolid.

We are recommending a series of thickening and de-watering equipment for the Authority. This includes the use of a rotary drum thickener for basic sludge thickening, as well as a screw press or centrifuge for de-watering capabilities. Table 9.4 at the end of this section provides a comparison of the equipment costs, annual O/M costs, labor requirements, and sludge cake produced for each of the processes.

## **A) ROTARY DRUM THICKENER**

A rotary drum thickener is a biosolids thickening system that commonly reduces the water content of biosolids, which in turn increases the digester capacity at the treatment facility. In general, these units are compact, requiring very minimal floor space, and operate with low horsepower and water consumption. Most units are constructed from stainless steel and will provide years of reliable service.

These systems utilize a low shear flocc tank to condition the influent biosolids, immediately followed by a de-watering “drum screen” to produce an effluent with approximately 5% to 6% solids content. The Authority completed a pilot study during April of 2010, using a Parkson Rotary Drum Thickener. The unit worked very well and produced an acceptable effluent biosolid for further digestion. A complete report is on file at the Authority office.

The rotary drum thickener will be designed to pull biosolids from the first digester, and then discharge effluent biosolids into the subsequent digester for further digestion. This process will provide increased digester capacity, as well as give the Authority another option for biosolids handling and treatment. Kruger and Alfa Laval also make rotary drum thickeners that would be acceptable for this project.

## **B) SCREW PRESS**

A screw press is a unique product, with the key to the process being a de-watering drum which can achieve both thickening and de-watering. Biosolids are fed into a mixing tank where polymer is added and thoroughly mixed. The biosolids then pass through a flocculation tank where gentle mixing occurs. From there, the biosolids overflow into the de-watering drum and are pressed through the thickening and de-watering zones. The result is a biosolid at approximately 15% solids that can be treated further to achieve class A status, or landfill applied as a top cover material.

The Authority also completed a pilot study on this technology, using a unit from PW Tech. The results were very good, and a complete report is on file at the Authority office.

This process would be applied after complete digestion has occurred. The biosolids would be pulled from the final digester, treated and then stored in a covered storage building for future disposal.

### **C) CENTRIFUGES**

As technology has advanced, centrifuges have become a more common form of sludge de-watering. Most digested sludges are conditioned with polymers before being fed into a centrifuge. Centrifuges are cylinders that rotate at extremely high speeds. The sludge is pumped to the center of the bowl where centrifugal force established by the rotating unit separates the liquid from the solids. The centrate (separated liquid) is then returned to the biological treatment process, while the sludge cake is removed to a hopper or conveyor for proper disposal, generally application to farm fields or sanitary landfill. The centrate generally contains higher amounts of suspended than other mechanical de-watering processes, and therefore treatment of the centrate may be required.

Centrifugation is recommended as a potential sludge de-watering alternative. The initial equipment cost and annual operating costs are higher than that of the vacuum filters and filter presses, however, they produce a cake with significantly higher solids content and operator requirements are reduced as the equipment requires only minimal supervision. Additionally, centrifugation is an effective first step in the process of agricultural utilization, as was previously recommended as a potential alternative.

A centrifuge pilot study will be completed in early July 2010.

**Table 9.4**

<b>PROCESS</b>	<b>EQUIPMENT COSTS</b>	<b>O/M COSTS</b>	<b>LABOR REQUIRED</b>	<b>% SLUDGE CAKE</b>
ROTARY DRUM THICKENER	\$400,000	\$7,000	PART TIME OPERATOR	5%
SCREW PRESS	\$315,000	\$5,000	PART TIME OPERATOR	15%
CENTRIFUGE	\$340,000	\$12,000	PART TIME OPERATOR	25%