



BROCKVILLE

CITY OF THE 1000 ISLANDS

BROCKVILLE WATER POLLUTION CONTROL CENTRE UPGRADE

CLASS ENVIRONMENTAL
ASSESSMENT REPORT

Technical Memorandum No. 2 Secondary Treatment Options Initial Review

Prepared By:



in association with



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Technical Memorandum No. 2: Secondary Treatment Options – Initial Review

1. Introduction

The City of Brockville is proceeding to complete a Class Environmental Assessment to assess alternative solutions for a proposed Brockville Water Pollution Control Plant (WPCC) Upgrade.

The upgrade works, as a minimum, are to provide the current “normal” level of treatment prescribed by the Ministry of Environment (MOE), which is considered as being secondary treatment or equal and consistent with the Provincial Guideline F-5.

This Technical Memorandum (TM#2) has been prepared to provide an initial review of various secondary treatment options. TM#2 identifies a short list of secondary treatment processes that based upon the initial review are considered most appropriate for the proposed Brockville WPCC Upgrade.

2. Secondary Treatment Processes

Treatment process options for the expansion on Brockville WPCC are wide ranging and may include all the processes shown in **Figure 1**. Secondary treatment technologies discussed in this section include the activated sludge process (ASP) (conventional, high-rate, step-feed, extended aeration), trickling filter/solids contactor (TF/SC), sequencing batch reactors (SBR), rotating biological contactor (RBC), biological aerated filter (BAF), biological nutrient removal (BNR), membrane bioreactors (MBR), and moving bed biofilm reactors (MBBR). **Figure 1** displays a chart of the various secondary treatment processes.

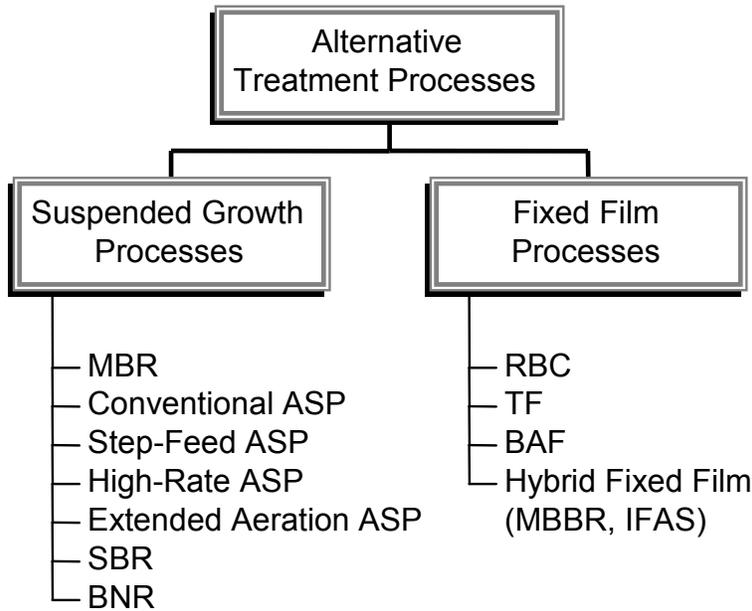


Figure 1: Alternative Secondary Treatment Processes

2.1 Activated Sludge Process (ASP)

Activated sludge process (ASP) is the mechanical process in most widespread use for the treatment of municipal wastewaters, including applications in Canada. It was developed in the United Kingdom in the early 1900s and several installations were put into operation in North America in the 1920s and then became more widespread in the 1940s. This process is a flexible process that, if designed well, can be used in a number of modified configurations. **Figure 2** shows a schematic of a typical activated sludge process configuration. The conventional and high-rate and stop-feed modifications of the ASP are described below.

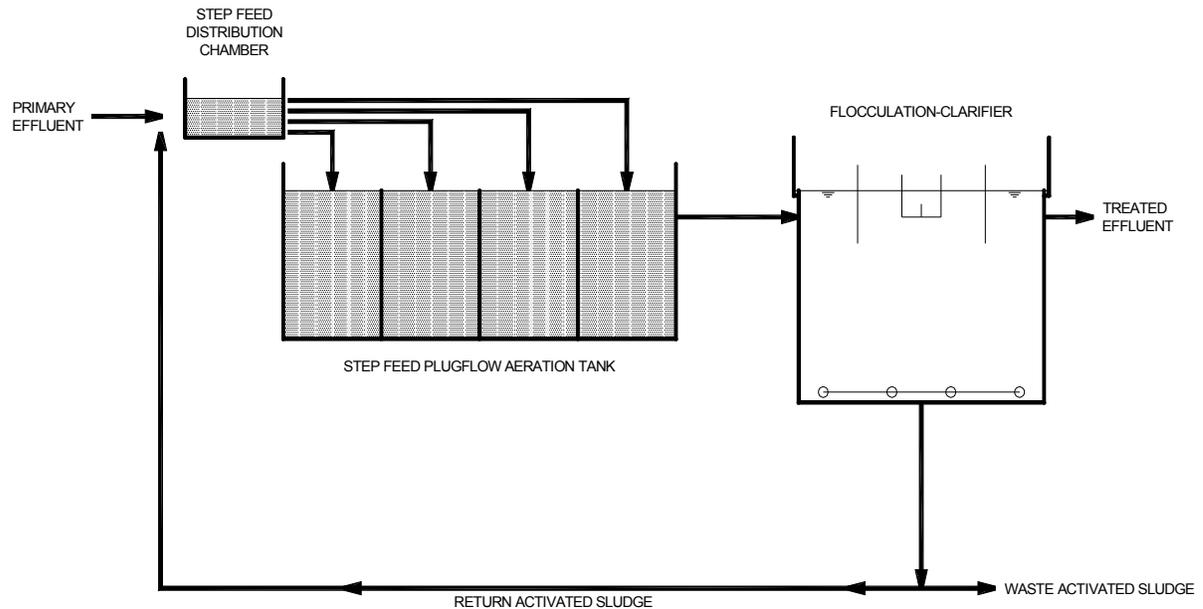


Figure 2: Typical Activated Sludge Process (ASP) Configuration

2.1.1 Conventional

Conventional ASP generally consists of a long and narrow aerated basin followed by clarification. Microorganisms are maintained in suspension by aeration and mixed for effective contact with the influent (i.e., substrate) and dissolved oxygen (DO). Air is typically used as an oxygen source and it is common to supply it to the basin by diffusers although other aeration systems can be used. Various configurations are available in either completely-stirred tank reactors (CSTRs) or plug-flow (PF) tanks. This discussion presents the plug-flow reactor, which is generally recommended. The basin acts as a plug flow reactor (i.e. series of CSTRs) with high concentration of biochemical oxygen demand (BOD) and microorganisms at the head of the basin, which react and decrease in concentration by the end of the basin. Effluent from the basin passes into the secondary clarifier where solids and microorganisms are settled out and are returned to the aeration basin. Excess sludge is wasted from the system and generally further processed prior to off-site beneficial use or disposal. The returned solids are sent back to the head of the aeration basin to help maintain the microbial concentration. This helps control the solids retention time (SRT) independent of hydraulic retention time (HRT) thus minimizing reactor volumes. Because the plug flow regime offers little dilution of the incoming flow, this process can be subject to upsets caused by shock loads and toxic material.

2.1.2 High-Rate

High-Rate ASP operates with high MLSS concentration and high volumetric loading, which allow for high food-to-microorganism (F/M) ratio thus providing a reduced hydraulic retention time (HRT). Adequate mixing is very important in order for this process to run effectively.

Experience at the Crystal Beach WPCP (Region of Niagara) and Little River PCP (Windsor), indicated adequate treatment could be obtained at aeration tank HRTs of 3.0 and 4.0 h, respectively for these two plants. The Little River PCP was able to provide both organic removal and nitrification at this optimized aeration tank HRT.

2.1.3 Step-Feed

Step-Feed is a modification of the conventional plug-flow process that provides the ability to avoid periodical solids washout of the final clarifier by retaining the solids in the front portion of an aeration tank. This is accomplished by distributing a portion of the primary effluent to point(s) along the aeration tank. It avoids the locally high oxygen demand and decreases the effect of peak hydraulic and organic loads. This process can help provide sufficient dilution to protect the microorganism against shock loads and toxic material. The potential disadvantage during periods of step-feed operations is a reduction in treatment due the shorter contact period, especially with regard to nitrification.

2.1.4 Extended Aeration

Extended aeration is a modification of the conventional activated sludge process that provides a long aeration tank retention time to provide complete organic removal and nitrification generally without primary clarifiers. Aeration tank retention times are generally 15 hours, or over twice that of a conventional ASP. Extended aeration is popular for small facilities for its ease of operation, reduce solids yields and generally good settleability. One disadvantage of the process is the lack of primary clarifiers for removal of inorganic material, scum and settleable solids and the need for separate thickening of both raw and biological sludges.

The oxidation ditch is a variant of the extended aeration system and consists of a ring- or oval-shaped channel or channels equipped with mechanical aeration and mixing devices. Like the extended aeration process primary clarification is not normally provided and retention times in the ditch are long, generally greater than 20 hours. Historically, these ditches used rotor type aeration for mixing and aeration and ditch depths were generally shallow, around 1.5 m. However, draft tube turbines, surface turbines or jet device can be used to allow for greater ditch water depth. Also variations are available that use a series of concentric channels within the same structure, thus avoiding any wasted area often observed at the center of oxidation ditches. These systems are sometimes proprietary equipment and

are patented, such as the Halo™ (Philadelphia Mixing Systems) and the TRI-OVAL™ (Aeration Industries International) oxidation ditch systems.

Generally, activated sludge facilities are characterized by:

- Aeration tank hydraulic retention time of 6 to 15 hrs
- Organic loadings of 0.17 to 0.72 kg BOD₅/m³.d
- Final clarifier surface overflow rate of 29 to 32 m³/m².d

The extended aeration process provides relatively increased hydraulic retention times and increased solids retention times (typically > 20 hours and 20 to 30 days respectively).

Example Activated Sludge Process facilities are:

- Ottawa ROPEC – conventional ASP
- Little River PCP (Windsor) – High Rate (or low HRT)
- Kemptville WWTP – Extended Aeration, nitrifying, with tertiary filtration

2.2 Trickling Filter/Solids Contactor (TF/SC)

The use of trickling filters with rock media was at its height in the United States during the 1940s. At that time nearly 60 percent of the secondary wastewater treatment plants in the U.S. were trickling filters. Activated sludge became more popular due to the trickling filter's higher initial capital cost and the need to meet more stringent effluent requirements.

A number of advances have occurred since the introduction of the trickling filter that makes it a potential candidate for a secondary facility with the increasingly stringent effluent requirements. These advances include the development of better media and the discovery of new combined processes. The development of new media including vertical filter media, horizontal filter media, random media, and cross flow media has increased the void area available compared to rock media. These new types of media provide increased air circulation, higher specific surface area for biological growth and the ability to slough off growth without plugging. Final clarification of TF effluent is required. A portion of this treated effluent is recirculated for control of media wetting.

Combined processes have improved the effluent quality and consistency attainable from the trickling filter process alone. The trickling filter/solids contact (TF/SC) process, **Figure 3**, is a hybrid system that combines the low-energy consumption and simple operation of a trickling filter with the excellent settling characteristics of a suspended growth system. The benefits

include organic removal and nitrification through the TF and superior solids flocculation and settling in the aeration component (i.e., solids contact system). The aeration component is referred to as a solids contact tank since its retention time is relatively short (e.g., 30 minutes or less).

There are many important design considerations for a TF/SC process. These considerations include periodic media flushing, solids contact operation, flocculating clarifier design, and reduced hydraulic gradeline and floc disruption to the solids contactor.

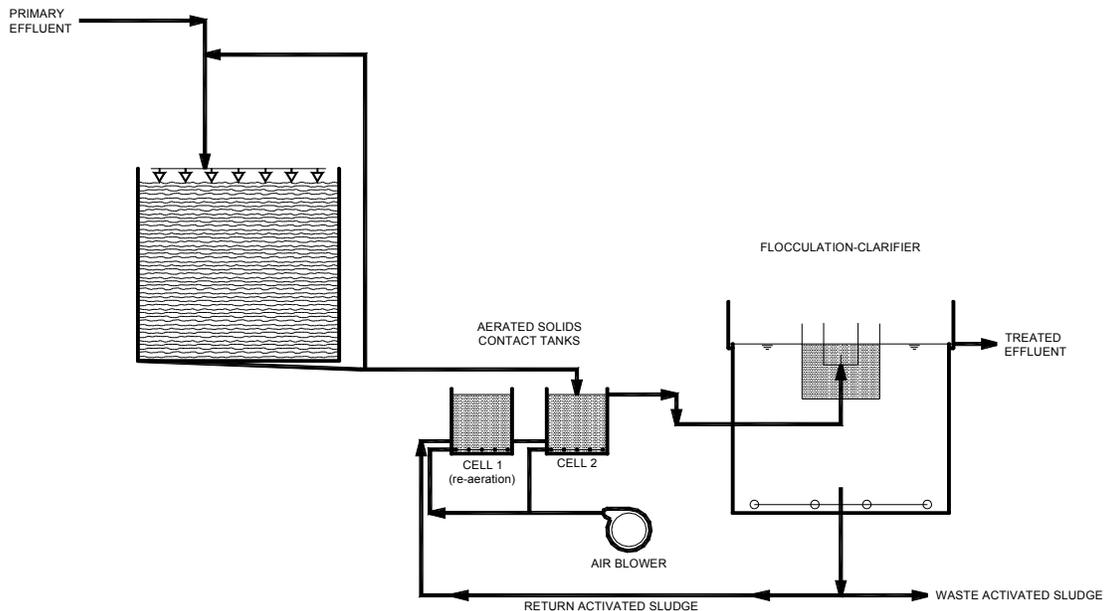


Figure 3: Typical Tricking Filter – Solid Contactor (TFSC) Process Configuration

Generally, TF/SC facilities are characterized by:

- Total organic loadings of $0.38 \text{ kg BOD}_5/\text{m}^3.\text{d}$ (for TF)
- Solids contactor HRT of 30 to 60 minutes
- Final clarifier surface overflow rate of $30 \text{ to } 60 \text{ m}^3/\text{m}^2.\text{d}$

Municipal TFSC facilities are not common in Ontario; an example facility in Canada is:

- Annacis Island WWTP (Vancouver, BC)

2.3 Sequencing Batch Reactors (SBR)

The operation of an activated sludge process using a "batch process" was identified in the early 1900s when activated sludge treatment was first discovered. The batch mode of operation was originally regarded as interesting but impractical. It is only over the last two decades that this mode of operation has earned attention, coinciding with the appearance on the market of programmable logic controls (1980) to overcome the basic step operational problems by automating the process. Evolution of the SBR process also corresponded to major discoveries in microbiology applied to wastewater treatment. These two "driving forces" (i.e., logic controls and applied microbiology) are responsible for today's growing recognition of the benefits of the batch mode of activated sludge system operation.

The SBR reactor is a mixed-culture, suspended growth activated sludge treatment system that is operated on a fill-and-draw basis; hence, the system can be broadly classified as an unsteady-state activated sludge system. Since SBRs use a single tank for waste stabilization and solids separation, the need for secondary clarifiers is eliminated. The semi-continuous operation of an SBR consists of five distinct phases (i.e., fill, react, settle, decant, and idle), as seen in **Figure 4**, which comprise one complete reactor cycle. The process biomass is sequentially subjected to alternating anaerobic, anoxic, and aerobic conditions in the biological reactor.

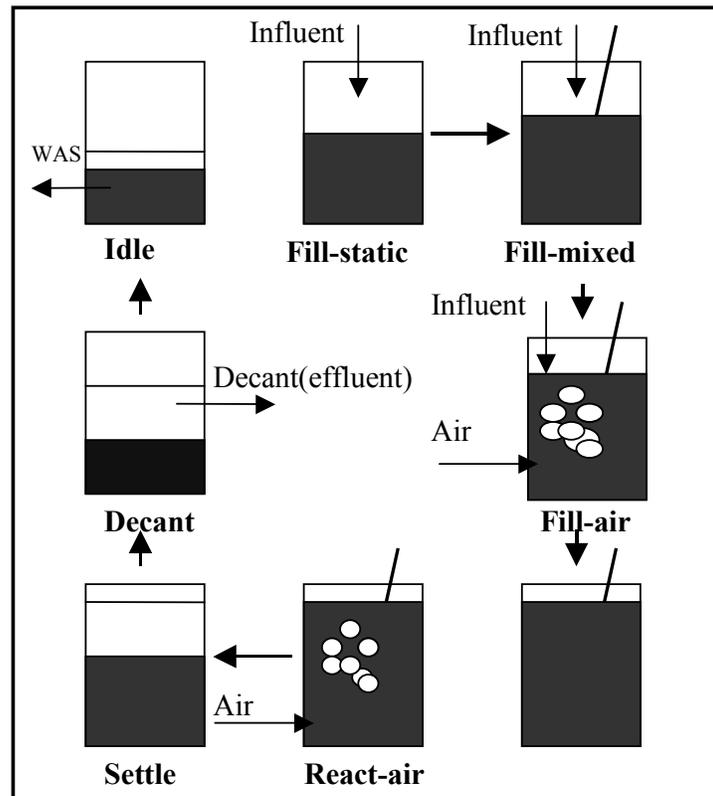


Figure 4: Five Phases of the SBR

Each tank in the SBR system is filled during a discrete period of time. During this “fill” period, organism selection can be controlled by manipulating the actual specific growth rates of the microbes and by regulating the oxygen tension in the reactor (e.g., from anaerobic, to anoxic, to fully aerobic). Thus, a “fill” period may be static, mixed, or aerated. After a tank is filled, treatment continues with the SBR operating as a batch reactor. During this “react” period, further selective pressures are applied by controlling the length of time the organisms are subjected to starvation conditions. After treatment the microbes are allowed to separate by sedimentation during a period called “settle”. The treated effluent is subsequently drawn from the reactor during an additional, distinct “decant” period. The period between “draw” and the beginning of the next cycle is “idle”, it provides excess capacity for times when the actual flow exceeds the average or design flow. Periodic sludge wasting can be implemented, as needed, during “react”, “settle”, “decant”, or “idle”. See **Figure 5** for a typical sequential batch reactor process configuration.

The SBR has been shown to be a cost effective and energy efficient means of removing hazardous organic compounds found in contaminated leachates and industrial wastewaters, and of removing organics and nutrients from municipal wastewaters. SBR’s are suited for the selection and enrichment of desired microbial populations because of the ease with which a diverse array of selective pressures can be implemented. The flexibility in its operation stems from the time-oriented nature of the process which, through simple operational modifications, can alter the nature and extent of organic carbon, nitrogen, and phosphorus removal. SBR’s can also be used to control bulking sludge, a common problem in continuous flow wastewater treatment systems.

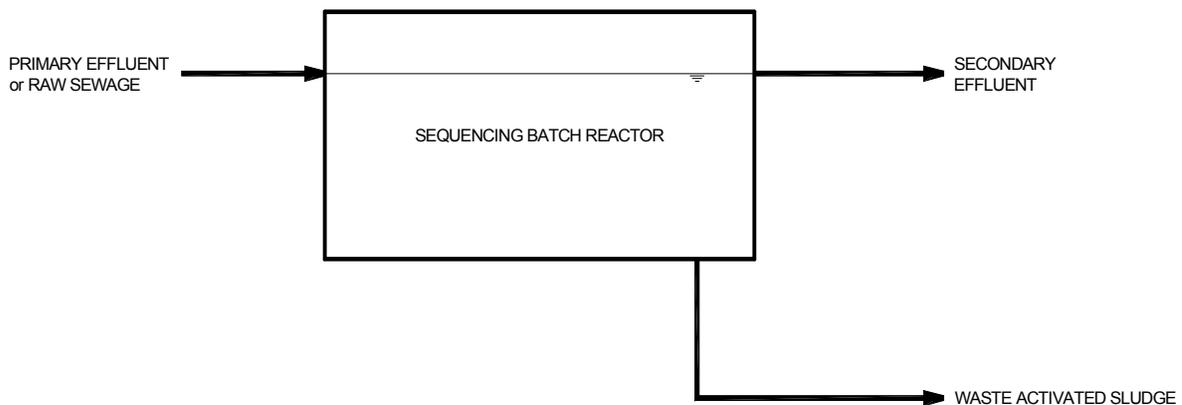


Figure 5: Typical Sequencing Batch Reactor (SBR) Process Configuration

SBR technology has been applied in well over 300 communities and industrial sites in Canada and the United States, as well as over 40 in Europe. Many of these facilities,

including those with BNR capabilities, have been meeting stringent effluent requirements for several years.

Generally, SBR facilities are characterized by:

- Reactor hydraulic retention time of 10 hrs
- Minimum of 2 SBR tanks

Example SBR facilities are:

- Rockland WPCP
- Cardinal WWTP

2.4 Biological Nutrient Removal (BNR)

In the late 1960's it was observed that several conventional, plug-flow activated sludge systems were accomplishing enhanced phosphorus removal. These systems appeared to be highly loaded plants operated to suppress nitrification. This led to the placement of an anaerobic zone at the head-end of plug-flow tanks to accomplish enhanced phosphorus removal, which was patented and referred to as the A/O process. Through pilot-plant and full-scale experimentation a three-stage process was developed, which was later patented as Anaerobic/Anoxic/Oxic or A2O. The Biological Nutrient Removal (BNR) process uses a combination of anaerobic, anoxic and aerobic zones and different recycle schemes (illustrated in **Figure 6**), to remove nitrogen and/or phosphorus from a wastewater stream without the addition of chemicals, although some addition for phosphorus polishing has been used, if required.

When operating an activated sludge system to accomplish BNR, one or more zones must be unaerated and a single sludge system must be used. Single sludge system means that each train contains only a single clarifier and return solids are recycled back through all zones. This is required for microorganism selection and the biochemical processes desired. Phosphorus removal is generally maximized by placing an anaerobic zone first in the train in order that phosphorus-removing bacteria have the first opportunity to utilize the organic substrate. This tends to give the phosphorus-removing bacteria a competitive edge over those bacteria that cannot utilize or store substrate under these conditions. Nitrogen removal can be maximized by placing the anoxic zone at the head end of the aeration system. Phosphorus removal can still be accomplished in this layout by locating the anaerobic zone after the anoxic zone, but only if readily available organics are still present. Nitrogen removal is less sensitive to the types of available organics so the anaerobic zone is usually placed first and the anoxic zone follows. Hence, this mode of operation involves cells that are maintained as either anaerobic or anoxic to provide nutrient removal in addition to organic

removal and nitrification. Such processes have, on occasion, been retro-fitted into an existing facility without any down-rating in capacity.

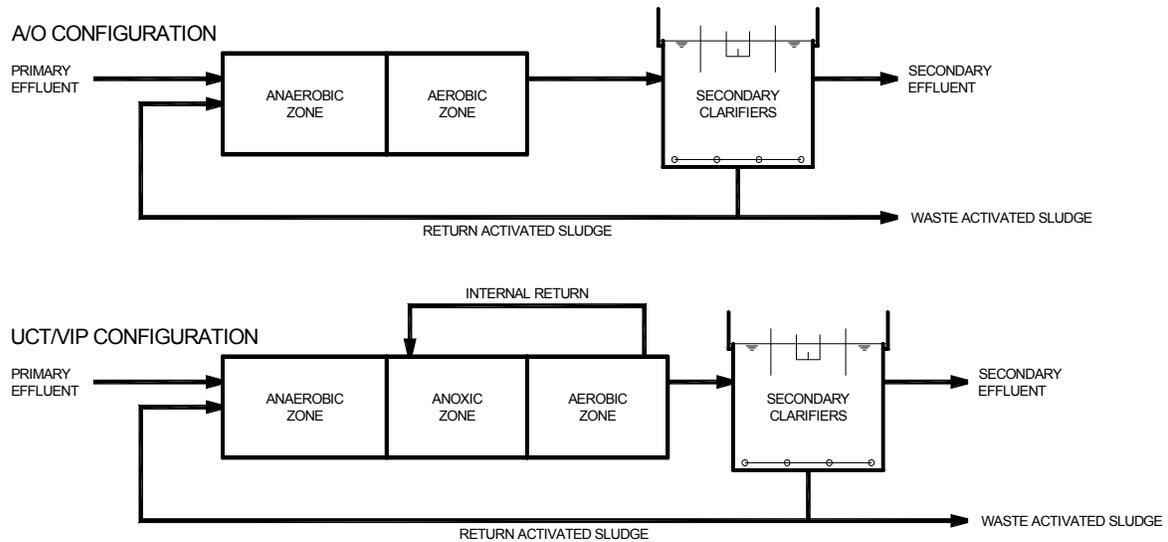


Figure 6: Typical Biological Nutrient Removal (BNR) Process Configuration

Operations of a BNR plant is generally more complex than a conventional activated sludge plant due to the internal recycles, different zone conditions and high degree of control required to ensure good performance. Lastly, control of solid handling streams and recycles must be carefully controlled or separately treated to avoid reintroduction of phosphorus (i.e. for biological P removal).

Generally, BNR facilities are characterized by:

- Aeration tank hydraulic retention time of 10 hrs or greater
- Final clarifier surface overflow rate of 29 to $\text{m}^3/\text{m}^2 \cdot \text{d}$

Example BNR facilities are rare in Ontario, but a few are designed for BNR (although may not be operating as such) including:

- Orangeville WPCP
- Elmira WPCP (Waterloo)

2.5 Membrane Bioreactors (MBR)

The membrane bioreactor (MBR) technology represents an advanced activated sludge wastewater treatment process that is capable of producing a suspended solids-free, tertiary treated quality effluent. The process combines a biological reactor with a membrane filtration system, **Figure 7**, for retention of the activated sludge. The most common MBR process configuration for the treatment of domestic wastewater involves direct in-situ filtration of mixed liquor by immersed microfiltration or ultrafiltration membranes, eliminating the need for external clarification and filtration.

High mixed liquor solids concentrations of 10,000 to 20,000 mg/L have been claimed in MBR systems, allowing elevated volumetric loading rates and compact process designs. Dedicated aeration systems below the immersed membrane modules are used for membrane scouring and control of fouling and flux. Maintenance of an acceptable filtrate flux requires relatively high-energy input and cleaning of the membranes with chemicals. This involves regular in-place mechanical and chemical cleaning and, occasionally, more extensive chemical cleaning of the membranes in an external cleaning tank.

MBR installations are in place for small-flow applications, mainly ranging between 10 to 200 m³/d. A number of applications involving higher wastewater flow rates of between 1000 to 7600 m³/d have been installed since 1997. Installations for flow rates of up to 40,000 m³/d will soon be coming on line.

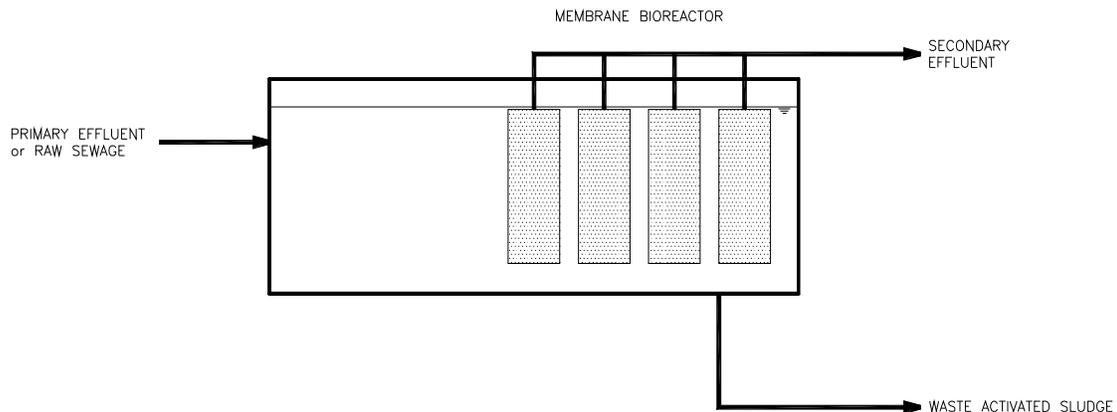


Figure 7: Typical Membrane Bioreactor Process Configuration

Generally, membrane bioreactor facilities are characterized by:

- Bioreactor hydraulic retention time of 4 hrs

Example MBR facilities are:

- Creemore WPCP, Township of Clearview
- Port McNicoll WWTP

2.6 Rotating Biological Contactor (RBC)

Development of the rotating biological contactor (RBC) process can be traced back to the 1920s in both Germany and the United States. Initial units were constructed with wooden disks as attached growth support surfaces that proved to be impractical to manufacture and prone to deterioration. In the 1950s experimentation began with plastic disks, which began to make the process viable. Units still had a higher capital cost, but required low maintenance and energy consumption. More compact disks were developed in the early 1970s with higher specific surface areas.

The RBC process typically involves a once-through flow arrangement comprised of a number of passes of rotating biological contactors (i.e., disc bundles mounted on rotating shafts) in series, separated by baffles. The rotating synthetic support media are kept in partial submergence (i.e., approximately 40%). The air-driven submerged biological contactor (SBC) with 75-90% submergence represents a relatively new alternative. The RBC or SBC effluent is clarified in a final clarification stage. **Figure 8** shows a schematic for a typical rotating biological contactor process configuration.

RBC plant operation depends on the organic and hydraulic loading rates. RBC plants that obtain effluent quality of 10 mg/L total BOD₅ and 5 mg/L NH₃-N are common. Plants are generally designed based on an organic and ammonia loading rate per unit surface area of media and a hydraulic loading rate. First stage loading rates are important to observe for design purposes. A range of reported organic loading rates vary from 1 to 29 g BOD₅/m²d. Hydraulic loading rates vary from 40 to 244 L/m²d. Manufacturers have reported loadings between 8 and 17 g BOD₅/m²d for combined BOD₅ removal plus 90 percent nitrification. Extensive pilot testing has shown that organic loadings between 6.0 to 6.5 g BOD₅/m²d can obtain an average effluent objective of 15 mg/L of BOD₅ and SS at a wastewater temperature of 10°C. To obtain nitrification to less than 5 mg/L TKN, at similar winter wastewater temperatures, maximum nitrogen loading of 0.4 g NH₃-N/m²d is recommended.

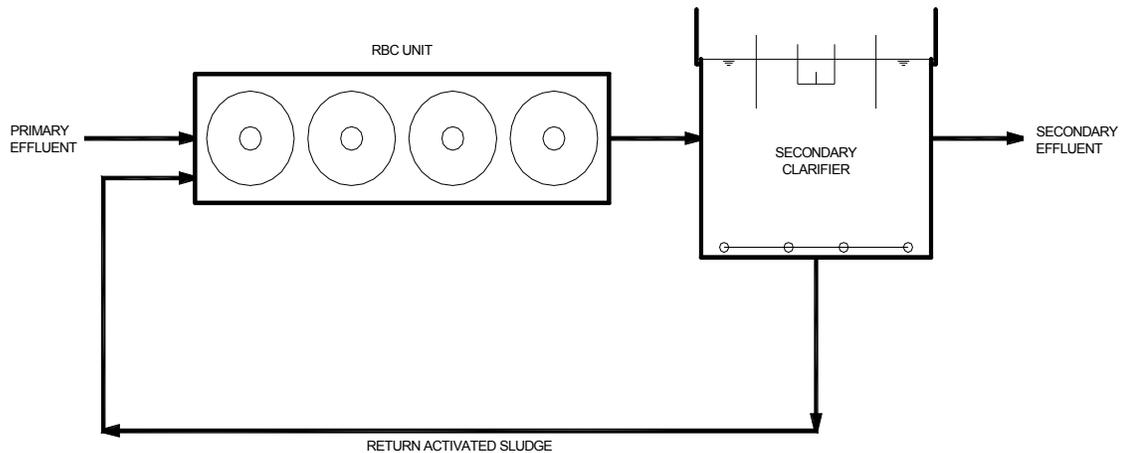


Figure 8: Typical Rotating Biological Contractor (RBC) Process Configuration

Final clarifier surface overflow rate (SOR) for an RBC process is recommended to be 16 to 20 $\text{m}^3/\text{m}^2\text{d}$ to meet effluent requirements between 10 to 15 mg/L SS. Precipitate (i.e. coagulant) or polymer addition may be required to obtain effluent SS concentrations between 10 to 15 mg/L. The West Windsor PCP (currently the Lou Romano WRP) has reported excellent performance at elevated peak SORs of 70 $\text{m}^3/\text{m}^2\text{d}$.

Previous issues of mechanical difficulties, including structural integrity problems (shaft failures and media deterioration due to overloading), typically reduce the acceptance of the RBC process, even though many of the initial concerns have been addressed via design improvements. The simplicity of the process has made it attractive for small community applications due to the low degree of operation, energy and maintenance required.

Some advantages of the RBC process are the ability to produce high quality effluent, a small land requirement, resistance to washout at high loadings (organic and hydraulic), small hydraulic grade-line, low energy consumption and simple operation.

Generally, RBC facilities are characterized by:

- Organic loading rate of 3.5 g $\text{BOD}_5/\text{m}^2\text{.d}$
- Final clarifier surface overflow rate of 30 to 70 $\text{m}^3/\text{m}^2\text{.d}$

Example RBC facility is:

- Niagara Falls WTPP

2.7 Biological Aerated Filter (BAF)

Biofiltration is a multi-purpose process that combines biological purification with solids filtration using attached growth biomass on an inert granular (expanded shale) or floating (styrene) media bed submerged in a single compact aerated reactor, **Figure 9**. The media typically consists of 2 to 5 mm diameter carrier particles. The BAF is an innovative treatment process in North America; the process is more common in Europe and Asia. Several commercial configurations are available. The main difference between the various processes is their flow orientation. BAFs are either downflow, with the influent flow counter-current to the process air, or upflow with the influent flow co-current to the process air. The first BAFs were downflow, based on laboratory and full-scale development of the technology in the mid-1970s. Newer installations generally employ upflow configurations to minimize backwashing frequencies and difficulties with media clogging. The City of Windsor extensively piloted this process in the mid 80's and is current designing a full-sale facility. The BAF process will be piloted at the Kingston Ravensview WWTP starting later this year.

The BAF process is compact (i.e., volumetric loading rates of up to an order of magnitude greater than with Trickling Filters) owing to concentrated biomass and the combined function of biological treatment and solids separation within a single reactor. The process is periodically taken off-line for backwashing with treated effluent. The BAF process is very much dependent on influent SS and BOD concentrations and generally requires effective primary treatment (i.e. enhanced primary treatment) and oil and grease control.

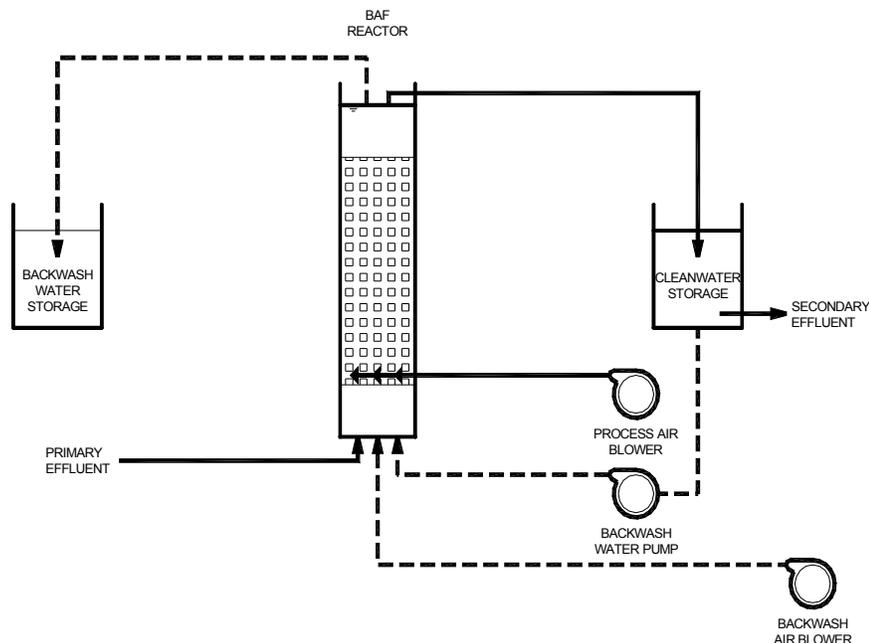


Figure 9: Typical Biological Aerated Filter (BAF) Process Configuration

Generally, BAF facilities are characterized by:

- Organic loading rate of 1.05 kg BOD₅/m³.d
- Tankage required for clean water and backwash (dirty solids) wells

Example facilities are not available in Ontario as of yet although facilities are under design and construction for Thunder Bay and Windsor. Facilities are in operation in Chatauguay WWTP (near Montreal), and Syracuse, N.Y.

2.8 Hybrid Fixed Film Processes (Moving Bed Biofilm Reactors (MBBR) or Integrated Fixed Film Activated Sludge (IFAS))

The patented moving bed biofilm reactor (MBBR) was collaboratively developed by Kaldnes Miljoteknologi and the Norwegian University for Science and Technology. This high rate aerobic process relies on the development of biofilm on small, lightweight, rigid plastic carrier media that fill the aeration tank and are kept in suspension by medium bubble aeration and/or mixing. Reactor effluent is clarified in a secondary clarifier from which there may or may not be recirculation of separated biomass. Refer to **Figure 10** for a typical moving bed biofilm reactor process configuration.

The cylindrical carrier elements possess high void space and a high specific surface area for attached growth (i.e., 350 m²/m³ at a maximum 70% reactor fill fraction) allowing for compact system designs. Screens are required at the inlet and outlet of the aeration tank(s) for media retention. Successful full-scale applications for municipal and industrial wastewater treatment have been reported. Biofilm reactors can be constructed without suspended growth, thus eliminating returns. Alternatively, suspended biofilm media can be used in conjunction with a conventional activated sludge process.

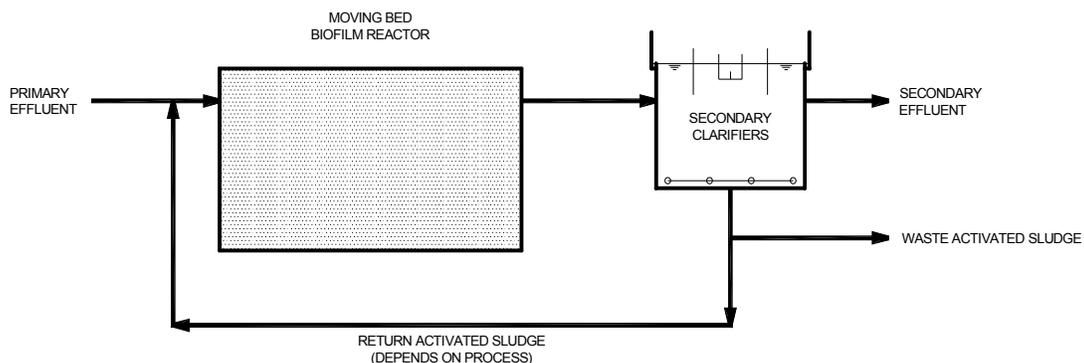


Figure 10: Typical Moving Bed Biofilm Reactor (MBBR) Process Configuration

Other hybrid fixed film processes are also available including:

- IFAS
- Captor and Linpor
- Ringlace

Generally, hybrid fixed film facilities, in particular MBBR are characterized by:

- Aeration tank hydraulic retention time of 4 to 6 hrs
- Organic loadings of 1.0 to 1.4 kg BOD₅/m³.d
- Final clarifier surface overflow rate of 30 to 40 m³/m².d

Example facilities are not available in Ontario although testing and piloting is being conducted at a number of facilities including:

- Waterdown WWTP (Hamilton)
- Humber WWTP (Toronto)
- Lakeview WWTP (Toronto)

3. Initial Evaluation of Secondary Treatment Options

Although, all secondary treatment processes outlined in this report can be implemented at the Brockville plant, some processes may be better suited than others. This section provides a general discussion of the specific benefits and limitations of each secondary treatment process for the Brockville WPCC.

3.1 Activated Sludge Process

The activated sludge process is the most common secondary process used throughout Ontario. This process also has the potential for upgrading and providing a flexible alternative for future needs. Of its various alternatives the high-rate with step-feed would be the most appropriate for the existing facilities, however extended aeration could be used in conjunction with the decommissioning of the primary clarifiers. The process is flexible and robust, although like most suspended growth systems is prone to settleability issues such as foaming and bulking.

3.2 Trickling Filter/Solids Contactor

This process tends to have a large hydraulic gradeline and would require pumping, increasing capital and operational and maintenance costs. It is a more complex secondary treatment having a limited degree of control. The footprint needs are also expected to be greater than other processes. Odours can also be an issue with this type of system and the large towers could be an aesthetic concern on the riverfront.

3.3 Sequencing Batch Reactors

SBR's are similar to the activated sludge process. This design uses a smaller footprint compared to ASP due to the common wall design of the basins. Subsequently, it utilizes less land. An advantage of the SBR is its ideal settling conditions, although controls for the process are more complex than most ASPs. Sequencing batch reactors are usually designed without primary clarifiers as extended aeration systems.

3.4 Biological Nutrient Removal

This process uses a larger footprint than an activated sludge process and has a higher capital cost. It is a more complex process to construct and operate with recycle flows and selector zones being controlled for producing sludge with good settleability. One advantage would be a reduction in chemical addition; however, current plant operations have benefited from pre-precipitation in the primary clarifiers. Also, total nitrogen removal is not required at the plant, nor is it expected in the future. Generally BNR facilities are considered to be more complex to operate than conventional ASPs.

3.5 Membrane Bioreactors

Membrane bioreactors are noted to provide an enhanced quality of effluent, but also have high energy and maintenance requirements relative to other activated sludge systems. They also have a small footprint that can be a site specific advantage. In addition, a number of smaller facilities have recently utilized this technology with promising results. The features of enhanced quality of effluent and small footprint are not a necessary requirement for Brockville.

3.6 Rotating Biological Contactor

This process allows for simple operation and requires a smaller footprint than ASP. The energy consumption is also lower than ASP. One disadvantage associated with the RBCs simplicity is the lack of available process control and adjustment if problems occur. The RBC process will meet the effluent criteria of the plant.

3.7 Biological Aerated Filter

Biological aerated filters can be located easily within the available plant site and would use the smallest footprint compared to the other processes reviewed. This process produces lower effluent concentrations than most of those mentioned above and the costs associated with this process are low. One disadvantage with the BAF is the backwash water and associated dilute waste solids produced that would require additional primary capacity or separate thickening. Of all the before mentioned secondary options, the BAF process would benefit most from being subsequent to continued enhanced primary treatment.

3.8 Hybrid Fixed Film Process or Moving Bed Biofilm Reactors

The Hybrid Fixed Film Process has been developed to integrate the advantages of both fixed film and suspended activated sludge in one process. The relatively high concentration of maintained biomass allows a higher organic loading rate, which offers reductions in aeration tank volumes or increased treatment capability within existing basins. Other reported advantages include lower net biomass production, enhanced nitrifying capabilities of fixed film growth, and process stability. In North America, this process is not as common compared to ASP, SBR and BAF. This process has numerous variations and can be more complex in terms of construction. Some concerns of screens and/or media being susceptible to clogging are noted.

4. Comparison of Most Appropriate Secondary Treatment Options

The review of preferred treatment process options for the Brockville WPCC Upgrade needs to reflect and evaluate priorities and issues unique to the WPCC. Key considerations identified for the initial review and general comparison include:

- Ability to meet effluent criteria/discharge requirements
- Degree of system/operational complexity
- Ability to treat and accommodate peak flows and loadings, and shock loadings
- Capital and operating costs
- Reliability/operating experience in municipal applications
- Solids and biosolids management

Based on an initial review and the above considerations, the secondary treatment processes considered most appropriate for further evaluation for the Brockville WPCC Upgrade include:

- a) Activated Sludge Process (ASP)**
- b) Sequencing Batch Reactor (SBR)**
- c) Rotating Biological Contractor (RBC)**

d) Biological Aerated Filter (BAF)

e) Hybrid Fixed Film Process (e.g. Moving Bed Biofilm Reactors (MBBR))

The following subsections present advantages and limitations of each process, expected effluent quality, and expected process footprint requirements for the above listed secondary treatment processes.

4.1 Advantages and Limitations of Secondary Treatment Options for Brockville

A comparison of the advantages and limitations for the listed secondary treatment technologies are summarized in **Table 1**.

TABLE 1: Advantages and Limitations of Secondary Alternatives		
Process	Advantages	Limitations
Suspended Growth Activated Sludge (ASP)	<ul style="list-style-type: none"> ➤ Common process ➤ Flexible process ➤ Upgrading potential ➤ BNR possible 	<ul style="list-style-type: none"> ➤ Sludge settleability can be a concern ➤ Foaming can be a concern ➤ High energy needs for aeration
Suspended Growth (SBR)	<ul style="list-style-type: none"> ➤ Aeration and clarification is combined in a single tank ➤ Very flexible for nutrient removal (i.e., BNR) 	<ul style="list-style-type: none"> ➤ Less common at larger scale ➤ More complex mechanical/electrical ➤ Discontinuous discharges
Fixed Film (RBC)	<ul style="list-style-type: none"> ➤ Simple process to operate and maintain ➤ High process stability ➤ Modular process ➤ Low energy needs 	<ul style="list-style-type: none"> ➤ Generally poor effluent aesthetics ➤ Limited degree of control ➤ Mechanical concerns
Fixed Film (BAF)	<ul style="list-style-type: none"> ➤ High loading rate; small footprint ➤ No final clarifiers required ➤ Modular process; upgrading potential ➤ Enhanced effluent quality ➤ High degree of automated control 	<ul style="list-style-type: none"> ➤ Complex mechanical/electrical and control systems ➤ Upstream screening, oil and grease removal ➤ Potential loss of media ➤ Less common process
Fixed Film – MBBR	<ul style="list-style-type: none"> ➤ Simple designs ➤ Retrofit of existing tankage ➤ Smaller footprint than ASP ➤ Low headloss; no backwashing 	<ul style="list-style-type: none"> ➤ Medium/Coarse bubble aeration ➤ Media retention screen assemblies ➤ Potential clogging of screens and bunching of media

4.2 Expected Effluent Quality

Adequate secondary effluent is possible from the secondary processes presented above. Actual performance will be site specific, some expected effluent quality concentrations are shown in **Table 2**.

TABLE 2: Expected Effluent Quality for Secondary Processes			
Process	Effluent Concentration (mg/L)		
	BOD ₅	SS	TP ¹
Modified ASP	15	15	0.5
SBR	15	15	0.5
RBC	15	15	0.5
BAF	8	10	<0.5
MBBR	15	15	0.5

Note: 1) with the aid of chemical addition

Generally, all processes are capable of meeting the MOE secondary process objectives of 15 mg/L, 15 mg/L and 0.5 mg/L for BOD₅, SS and TP, respectively, if optimized and operated effectively. The BAF will have enhanced solids removal, phosphorus removal and BOD₅ removal.

4.3 Unit Process Land Requirements or Footprint

The expected footprint required for each unit process (excluding other site requirements) is based on expected loading rates and tank geometry and is provided for comparative purposes only.

Table 3 provides the basis for providing a footprint for each unit process. **Table 4** provides the footprint based on the unit loading outlined in **Table 3**.

TABLE 3: Loading Basis for Process Footprints		
Process	Loading (units)	Value
ASP (modified to extended aeration)	Aeration HRT (hr)	3 - 15
	Clarifier SOR peak (m ³ /m ² .d)	29.4
SBR	Reactor HRT (h)	10
RBC	TOL (g BOD ₅ /m ² .d)	3.5
	Clarifier SOR peak (m ³ /m ² .d)	40 – 70
BAF	TOL (kg BOD ₅ /m ³ .d)	1.05
	Clean Water/Backwash Wells	10% each of cell volume
MBBR	Reactor HRT (hr)	4
	Clarifier SOR peak (m ³ /m ² .d)	30 - 40

Process	Surface Area (m ²)
Activated Sludge Process (modified to extended aeration)	2,400 – 4,600
Sequencing Batch Reactor	1,800
Rotating Biological Contactor	1,900
Biological Aerated Filter	400
Moving Bed Biofilm Reactor	2,600

Comparative process footprint areas are for the liquid train secondary treatment processes only. The calculated surface area requirements do not account for additional facilities and buildings such as blower and return-activated-sludge buildings. Overall, the results show that modified activated sludge process has the largest footprint (based on the indicated loading range) requirement, followed by the Hybrid Fixed Film/MBBR, RBC, SBR, and BAF process. The BAF process requires the least secondary treatment area as it combines biological treatment and solids separation within a single reactor (i.e. no secondary clarifiers) which can be very beneficial if land area is critical or complete enclosure of the facility is considered. The MBBR, SBR or extended aeration processes may be able to be designed without primary clarification, and therefore the existing clarifier 1,060 m² surface area could be considered as a reduction from the required surface area indicated in **Table 4** for these processes.

The Brockville WPCCC site appears to have sufficient land for any of the above process options. However, minimizing the required footprint helps to keep on-site land available for future uses and reduces the potential aesthetic impact of larger facilities.

5. Other Options or Considerations

Further to the review provided in this technical memorandum, subsequent considerations of options and items relating to the identified process treatment options will include:

- Process options and variations
- Waste activate sludge handling considerations
- Biosolids stabilization considerations
- Septage receiving implications
- Disinfection options