

Appendix 2-1

Sewage Treatment Process Options

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1 Introduction

The purpose of this document is to provide general descriptions and operating experience of the possible sewage treatment options that have been considered for the selection of the Pillar Point Sewage Treatment Works (PPSTW) upgrading works, which include (1) Chemically Enhanced Primary Treatment (CEPT) processes and (2) compact secondary treatment processes.

This document is structured as follows:

- **Section 1** introduces the purpose and structure of this document.
- **Section 2** describes the Chemically Enhanced Primary Treatment (CEPT) process options
- **Section 3** describes the compact secondary treatment process options
- **Section 4** presents the summary of this document

2 Chemically Enhanced Primary Treatment (CEPT) Processes

Sedimentation / Clarification, the separation of suspended and colloidal materials heavier than water by gravitational settling, is one of the most widely used unit operations in wastewater treatment. Primary clarification aims at removing readily settleable solids and floating material and thus reducing the suspended solids contents.

Chemically enhanced primary treatment (CEPT) is the process by which chemicals, typically metal salts (like Ferric Chloride and Alum) and / or polymers in the form of organic polyelectrolyte, are added and followed by primary sedimentation basins. The chemicals cause the suspended particles to clump together through coagulation and flocculation. The particle aggregates, or flocs settle faster thereby enhancing treatment efficiency.

The following CEPT options, including available propriety high rate clarification processes, have been identified:

- CEPT with Primary Clarifiers (Single-deck)
- CEPT with Primary Clarifiers (Multi-level)
- CEPT with Lamella Clarifiers
- Actiflo Process (Proprietary High Rate Clarification Process)
- DensaDeg (Proprietary High Rate Clarification Process)

General descriptions of the above five CEPT options are provided in the following sections.

2.1 CEPT with Primary Clarifiers (Single-deck)

The schematic diagram of typical CEPT with primary clarifier is shown in **Figure 2.1.1**. Conventional primary clarifiers (single-deck) use very large basins and allow the settling of the floc to occur by gravity. A typical rectangular primary sedimentation tank is shown in **Figure 2.1.2**.

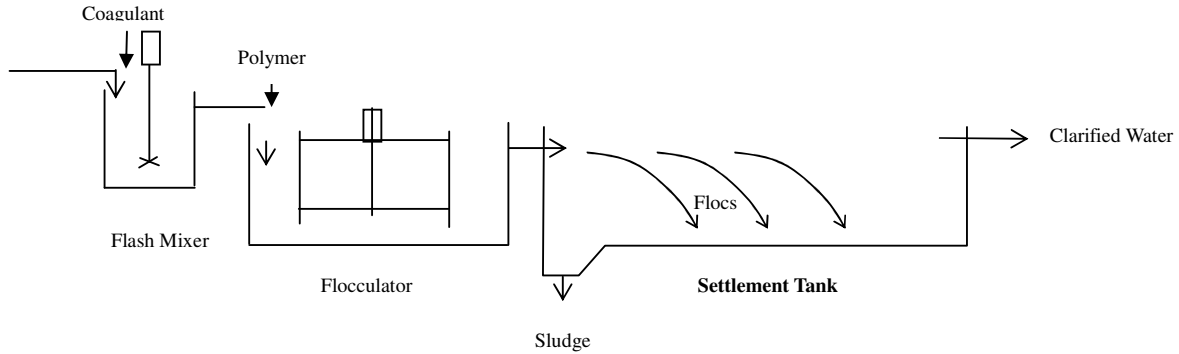


Figure 2.1.1 Schematic Diagram of Typical CEPT Process

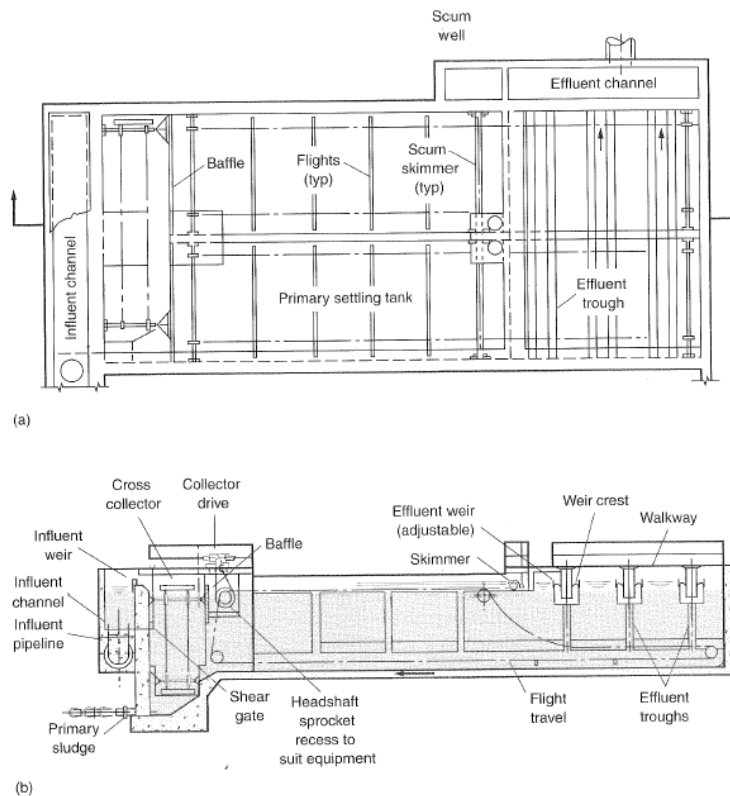


Figure 2.1.2 Typical Rectangular Primary Sedimentation Tank: (a) Plan and (b) Section

2.2 CEPT with Primary Clarifiers (Multi-level)

Multilevel rectangular clarifiers are similar to conventional rectangular clarifiers (single-deck) in terms of influent and effluent flow patterns and solids collection and removal efficiency. The multilevel clarifiers are actually two (or more) tanks, one located above the other, operating on a common water surface (**Figure 2.2.1**), which save space compared to the single-deck clarifiers. Each clarifier is fed independently, resulting in parallel flow through the lower and upper tanks.

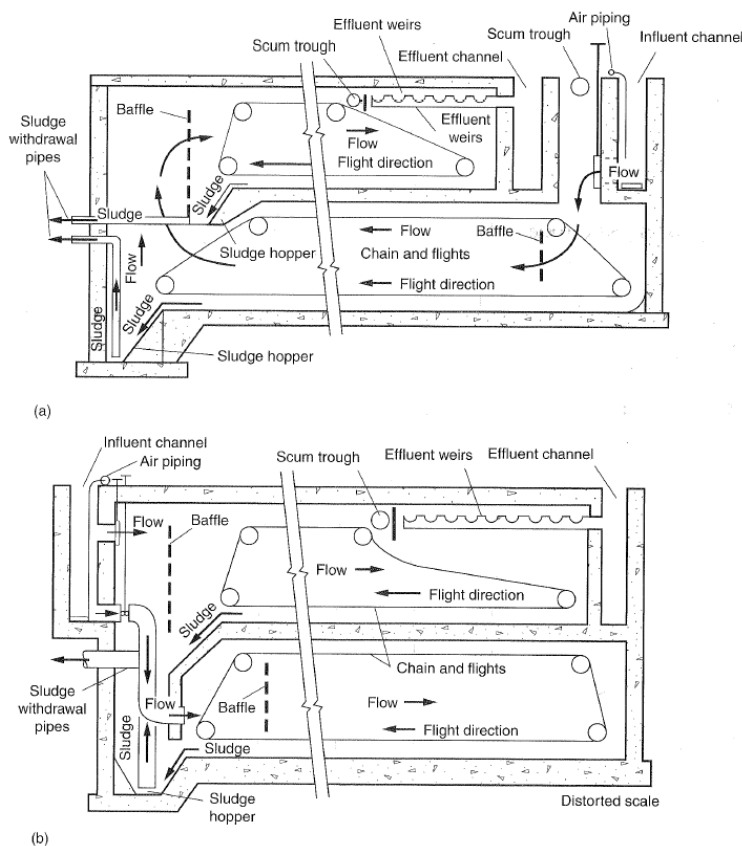


Figure 2.2.1 Typical Section through a stacked clarifier:
(a) Series Flow and (b) Parallel Flow

The general TSS removal and BOD removal of CEPT with primary clarifiers are 70-90% and 50-80% respectively. There are four CEPT sewage treatment plants, namely Stonecutters Island STW, Siu Ho Wan STW, Cyber Port STW and Sham Tseng STW, commissioned in Hong Kong.

The CEPT primary treatment facilities (double-deck sedimentation tanks) at the Stonecutters Island STW, which is the first CEPT primary treatment works in Hong Kong,

was fully commissioned in December 2001. Based on the historical data in Stonecutters Island STW, it showed that the CEPT process can achieve the minimum removal efficiency of 70% and 55% for TSS and BOD for most of the time. However, the performance of BOD removal should be related to the fraction of soluble BOD to total BOD in the wastewater as the BOD in soluble form is difficult to be settled.

2.3 CEPT with Lamella Clarifiers

Conventional gravity settling is based on the tendency of heavier particles to settle in a quiescent liquid medium. Regardless of its volume, a conventional clarifier produces clear water at a rate proportional to its surface area. Inclined plate / Lamella and tube clarifiers are shallow settling devices consisting of stacked offset trays or bundles of small plastic tubes of various geometries. By utilizing evenly spaced plates or tubes as settling surfaces, lamella type clarifier is capable to place large settling volumes in a relatively small area, because the effective gravity settling area of the inclined plate design equals each plate's area projected on a horizontal surface as shown in **Figure 2.3.1**. The typical Inclined Plate Settler is shown in the **Figure 2.3.2**.

In Hong Kong, there is a lamella plate installation in Stanley STW for final sedimentation process and there are several small-scale systems in Outlying Islands. There are also some overseas installations of lamella settling in wastewater treatment plants. The general TSS removal and BOD removal of CEPT with lamella clarifiers are 70-90% and 50-80% respectively, which are similar to the performance of CEPT with primary clarifiers.

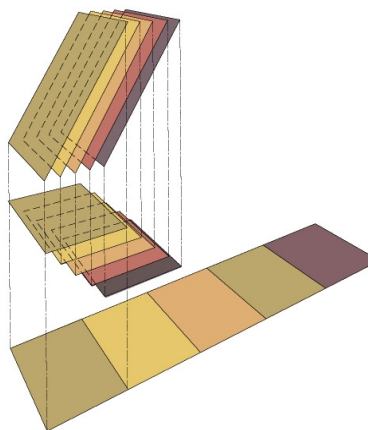


Figure 2.3.1
Theoretical Settling Area of
Lamella Clarifiers

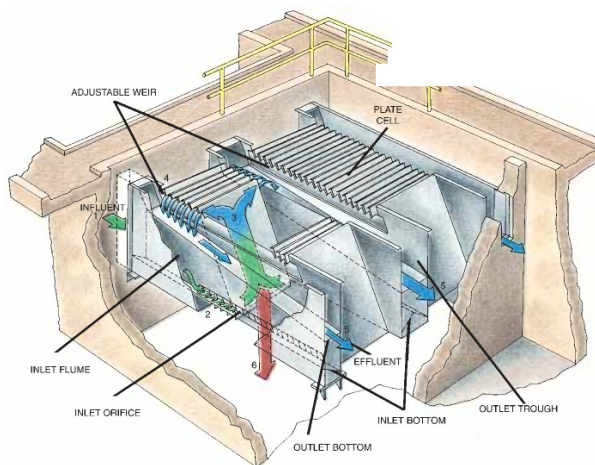


Figure 2.3.2
Typical Rectangular Lamella Plate Settler in Concrete
Basin

2.4 Actiflo Process (Proprietary High Rate Clarification Process)

Actiflo is a compact high- rate clarification system using microsand combined with polymer for improved floc attachment and thus improves settling. It employs physical/chemical treatment and utilizes special flocculation and sedimentation systems to achieve rapid settling. The essential elements of high-rate clarification are enhanced particle settling and the use of inclined plate or tube settlers. There are 5 main steps in Actiflo process and the typical schematic diagram of Actiflo process is shown in **Figure 2.4.1**.

Actiflo process has for many years been used for producing drinking water, especially in European countries (e.g France), and is now to an increasing extent being used for treatment of wastewater. Until 2004, there are more than 130 potable water installations, 50 wastewater installations, 40 industrial wastewater installations and 25 stormwater installations worldwide. The largest Actiflo installations are in France. The general TSS removal and BOD removal of CEPT with lamella clarifiers are 70-95% and 50-80% respectively, which are similar to the performance of CEPT with primary clarifiers.

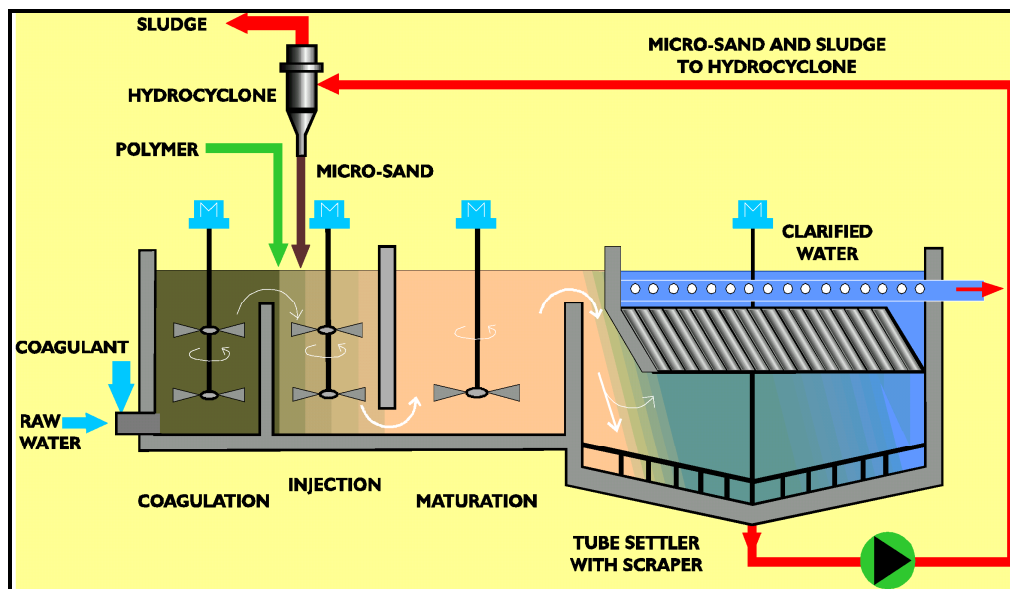


Figure 2.4.1 Actiflo Ballasted Flocculation and Settling Process

2.5 DensaDeg (Proprietary High Rate Clarification Process)

The DensaDeg process is another proprietary high rate clarification process. Similar to the Actiflo process, it is enhanced particle flocculation process, which involves the addition of a ballasting agent, a coagulant and a polymer for the formation of ballasted floc. This floc is then settled in a lamella clarifier. However, different from Actiflo process, this process uses recycled chemically conditioned sludge to build larger and denser flocs with incoming wastewater instead of microsand. Only conventional reagents (coagulant and polymer) are used for coagulation and flocculation, so the operation is relatively easier than Actiflo process.

Typically, DensaDeg type 2D has three major components including: (1) Reactor Zone, (2) Presettling / Thickening Zone, and (3) Clarification Zone, as shown in **Figure 2.5.1** and **Figure 2.5.2**.

DensaDeg process has more than 321 full-scale installations around the worldwide in the past 20 years. Most installations are located in Europe, North America, China and Korean for various purposes. The general TSS removal and BOD removal of CEPT with lamella clarifiers are 80-90% and 50-80% respectively, which are similar to the performance of CEPT with primary clarifiers.

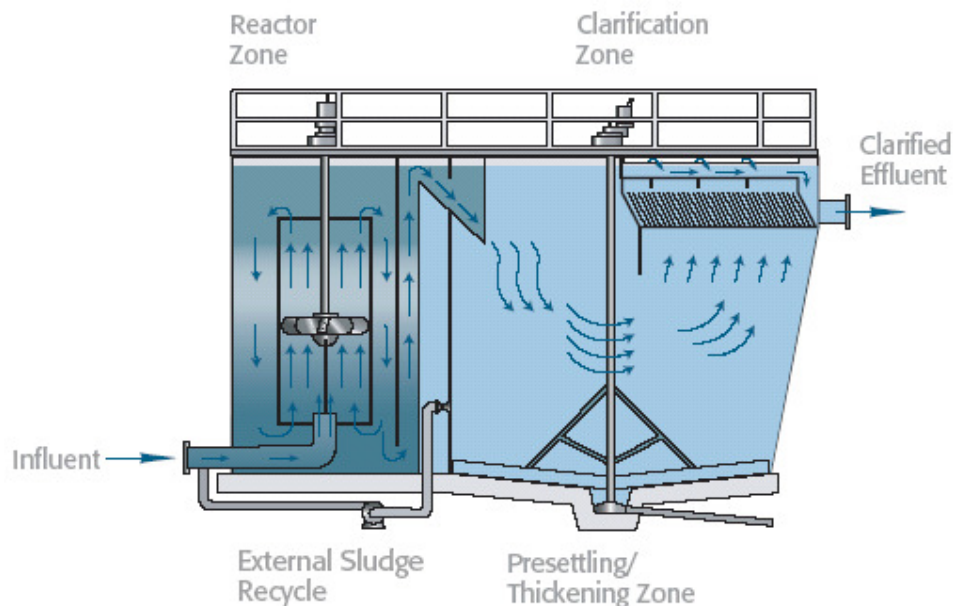


Figure 2.5.1 Schematic Diagram of DensaDeg Process (Sectional View)

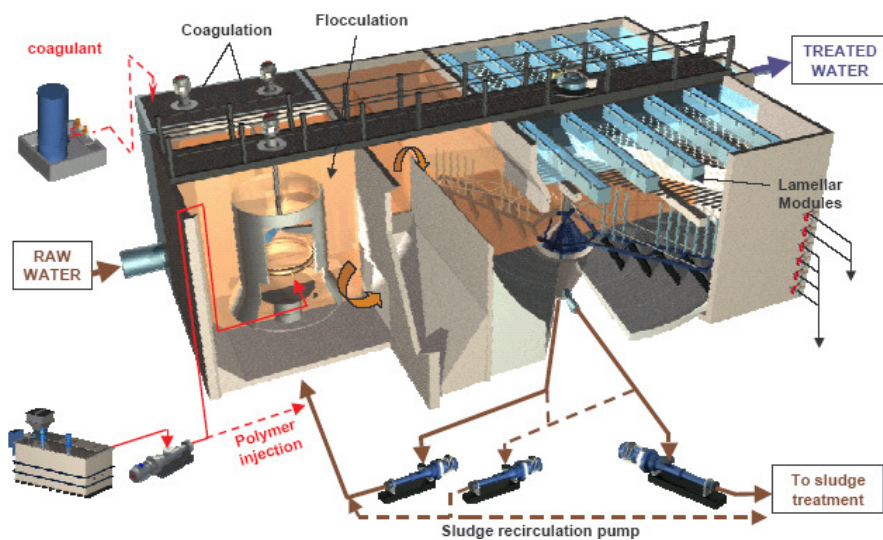


Figure 2.5.2 Schematic Diagram of DensaDeg process (3-Dimensional View)

3 Compact Secondary Treatment Process

The overall objectives of the biological treatment of domestic wastewater are to (1) transform (i.e. oxidize) dissolved and particulate biodegradable constituents into acceptable end products, (2) capture and incorporate suspended and nonsettleable colloidal solids into a biological floc or biofilm, (3) transform or remove nutrients, such as nitrogen and phosphorous, and (4) in some cases, remove specific trace organic constituents and compounds.

The removal of dissolved and particulate carbonaceous BOD and the stabilization of organic matter found in wastewater are accomplished biologically using a variety of microorganisms, principally bacteria. Microorganisms are used to oxidize (i.e. convert) the dissolved and particulate carbonaceous organic matter into simple end products and additional biomass.

Normally, the secondary treatment process is located after the primary clarifiers. As such, the total area required for implementation of secondary treatment should be larger. In view of the land constraint, compact secondary treatment processes are considered for the PPSTW upgrading works. However, conventional activated sludge process is the most common secondary process being used in Hong Kong and so it will also be considered for completeness. The list of the secondary processes is summarized as follows:

- Biological Aerated Filter (BAF)
- Sequencing Batch Reactors (SBR)
- Membrane Biological Reactor (MBR)
- Activated Sludge Process

General descriptions of the above four biological treatment processes options are provided in the following sections.

3.1 Biological Aerated Filter (BAF)

Biological Aerated Filter (BAF) is a fixed-film system in which a biofilm-support filter medium is submerged in wastewater to provide biological treatment. In the original BAF designs, the entire filter is aerated by introducing air at the base of the reactor via a network of diffuser nozzles, discs or tiles. Secondary clarification is not required for BAFs, since the biomass remains attached to the filter media. The filters are periodically backwashed to remove excess biomass, and the dirty backwash water is recycled.

BAF is a highly compact process. Its reactor size requirement is significantly smaller than that for the activated sludge process because of its high biomass concentration in the filter media. Also, BAF saves the space required for separate secondary clarifiers. The primary concern for using BAF process is its lack of operating experience in Hong Kong, complex mechanical equipment and controls, and probably high capital and O&M costs. There are some associated processes units currently required for the BAF process, depending on the BAF design. These process units include:

- Pre-treatment (for some BAFs only)
- Filter backwashing system
- Filter backwash prethickening system
- Chemical addition
- Intermediate or effluent pumping

Figures 3.1.1 and 3.1.2 show the schematics for the alternative configurations for a BAF reactor.

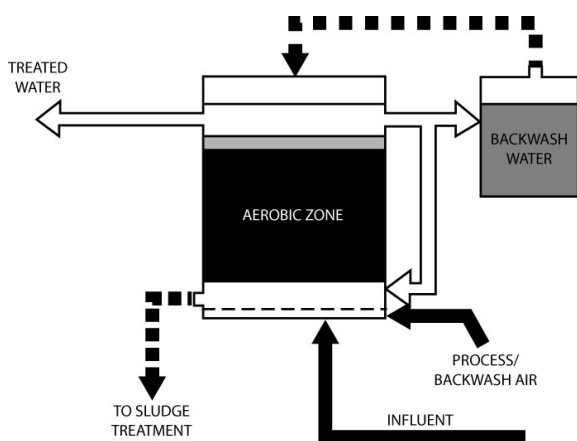


Figure 3.1.1
Upflow Floating Granular Media Cocurrent
Process Air

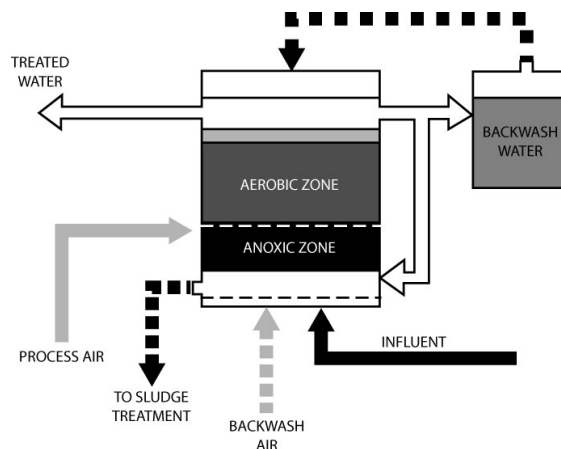


Figure 3.1.2
Upflow Floating Granular Media Cocurrent
Process Air Nitrification/ Denitrification

The BAF process has been used in municipal STW for nearly 20 years. The first BAF plant was commissioned in 1982 in Soissons, France. In early 1990, about 100 BAF plants were built around the world (Payraudeau et. al. 1990), mostly in sites with restricted area and stringent effluent quality requirements. Most of the installations are located in Europe and the installations in U.S. are relatively limited.

3.2 Sequencing Batch Reactors (SBR)

The sequencing batch reactor (SBR) is a fill-and-draw activated sludge treatment system. It includes a generic system of variable volume activated sludge in which aeration, sedimentation and decant are combined in a single reactor. Consequently, there is no dedicated secondary clarifier or associated return sludge facilities.

The operation of the SBR, shown in **Figure 3.2.1**, consists of five distinct periods, which comprise one complete reactor cycle. 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. 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 DRAW period. IDLE, the period between DRAW and the beginning of the next cycle, 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, DRAW or IDLE.

SBR is now considered to be a proven sewage treatment technology. The operating experience of SBR systems is extensive. SBR has been used in municipal STWs for over 30 years. This technology had been used in the 70s in Canada, the U.S. and Europe. It was also popular in Australia since the same period. Currently, SBR technology has been applied in over 500 communities and industries in the U.S. and Canada, and over 400 in Europe. Most of the SBR installations are small (less than 4000 m³/d). There are a few major SBR plants that have recently been commissioned, including the Yannawa STW in Bangkok with design capacity of 200,000 m³/d.

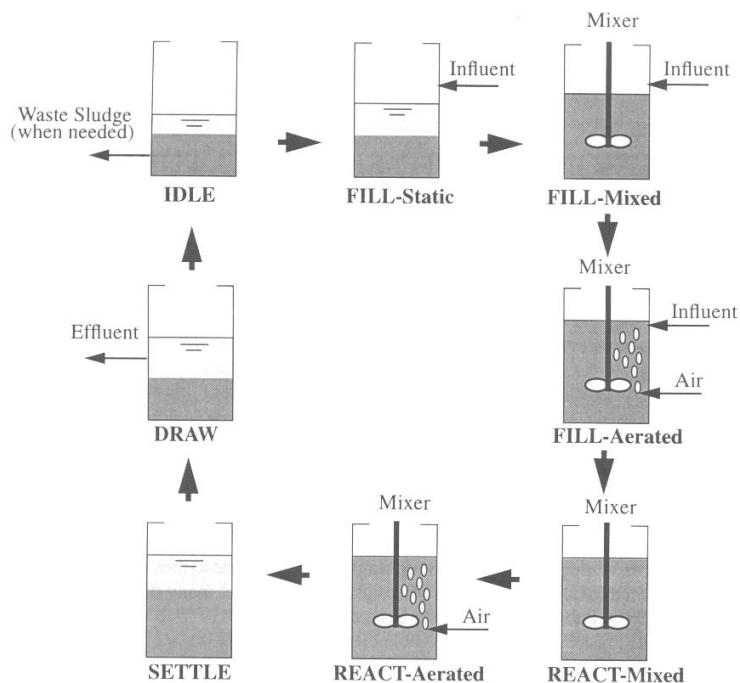


Figure 3.2.1 Operation of SBR

3.3 Membrane Biological Reactor (MBR)

Membrane bioreactor (MBR) process is a modification of the activated sludge process. Its key feature is that the liquid-solids separation is carried out by highly specialized membranes, as compared with the secondary settler in the continuous-flow activated sludge process. Also, elevated mixed liquor suspended solids (MLSS) levels (8,000 to 12,000 mg/L) are generally maintained in bioreactors to increase the treatment efficiency.

The separation of activated sludge and effluent takes place using membranes, where all the suspended materials is removed from the water. The membrane materials include polymeric materials (e.g. polyethylene) or ceramics. These materials are porous and achieve solids and liquid separation mechanically. The pore sizes of the membranes that are commonly used range from 0.03 to 0.4 μm , which are sufficiently small to remove nearly all suspended solids material, mainly biomass within the bioreactor while producing a clarified effluent.

The MBR process can exist in two different configurations (see **Figure 3.3.1**). The first configuration is a side-stream system, in which the membrane is independent of the bioreactor. The MLSS of the bioreactors is pumped around a recirculation loop containing a membrane unit where the permeate is discharged and the retentate is returned to the

bioreactor. The second configuration is a submerged MBR, in which membrane modules are immersed within the bioreactor. This is currently the most common MBR configuration for municipal applications.

The operating experience of MBR is limited when compared with other processes especially for major municipal plants. Currently, there are about 50 MBR installations for municipal treatment applications. Most facilities are less than 3000 m³/d and have been in operation for less than 5 years. There are about 24 municipal WWTP using MBRs within the U.S., and there are approximately 9 installations in Canada. There are also about 20 municipal MBR plants in Europe.

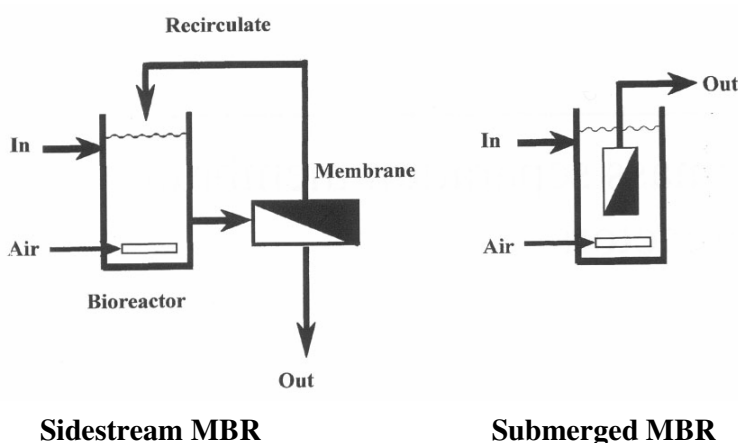


Figure 3.3.1 MBR Configurations

3.4 Activated Sludge Process

The principal biological processes used for wastewater treatment can be divided into two main categories: suspended growth and attached growth (or biofilm) processes. The activated-sludge process is the suspended growth process and now used routinely for biological treatment of municipal wastewaters. The wastewater is aerated and there is a production of an activated mass of microorganisms capable of aerobic stabilization of organic material in wastewater.

The basic activated sludge treatment process (**Figure 3.4.1**) consists of the following three basic components: (1) a reactor in which the microorganisms responsible for treatment are kept in suspension and aerated; (2) liquid-solid separation, usually in sedimentation tank; (3) a recycle system for returning solids removed from the liquid-solids separation unit back to the reactor. Numerous process configurations have

evolved employing these components.

The activated-sludge process is now used routinely for biological treatment of municipal wastewaters and there are plenty of local operating experiences. The major local secondary treatment works are Shek Wu Hui STW, Yuen Long STW, Tai Po STW, Shatin STW, Sai Kung STW and Stanley STW. Normally, biological process is adopted not only for carbonaceous organic matter removal, but also for the nitrogen removal. As such, designs employ reactors in series, operated under aerobic, anoxic, anaerobic conditions, are common.

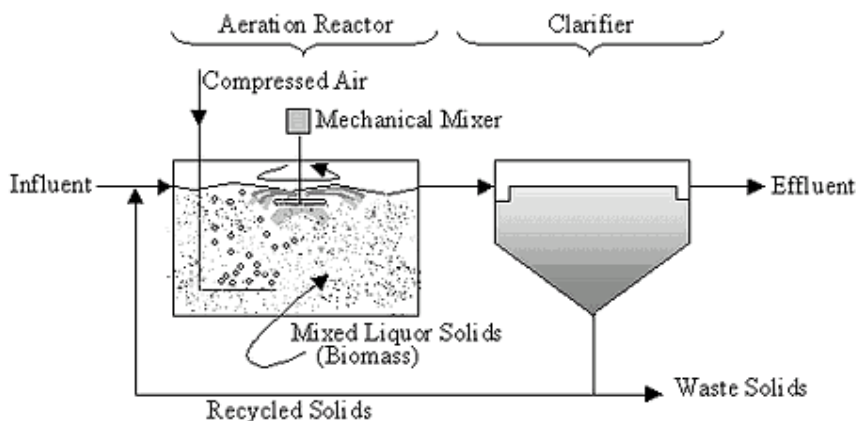


Figure 3.4.1 Schematic Diagram of Activated Sludge Process

4 Summary

The five CEPT options are all with similar TSS and BOD removal efficiency, whilst the four secondary treatment processes generally have an advantage of producing better quality of treated effluent over the CEPT processes. As described in Section 2 and Section 3 of this document, all the CEPT options and secondary treatment processes are capable to remove TSS and BOD in the sewage without creating new element in the effluent. The sludge generated in the treatment process (CEPT sludge from CEPT process and waste sludge from secondary treatment) is collected and treated separately. Hence, no water quality and ecological impacts will be made.

As all the possible CEPT options and secondary treatment processes are with similar treatment efficiency, the selection of the processes are therefore mainly referring to their advantages and disadvantages on different areas of engineering aspects, which are “Sludge Production”, “Ease of Operation”, “Hydraulic Head Requirements” and “Land Requirement” as discussed in Section 2.6.2 of the EIA Study Report.