AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

AquaPASS® Phased Activated Sludge System Operational Description

The AquaPASS System Overview:

The AquaPASS® Phased Activated Sludge System consists of the following basins, in order of introduction of process flow:

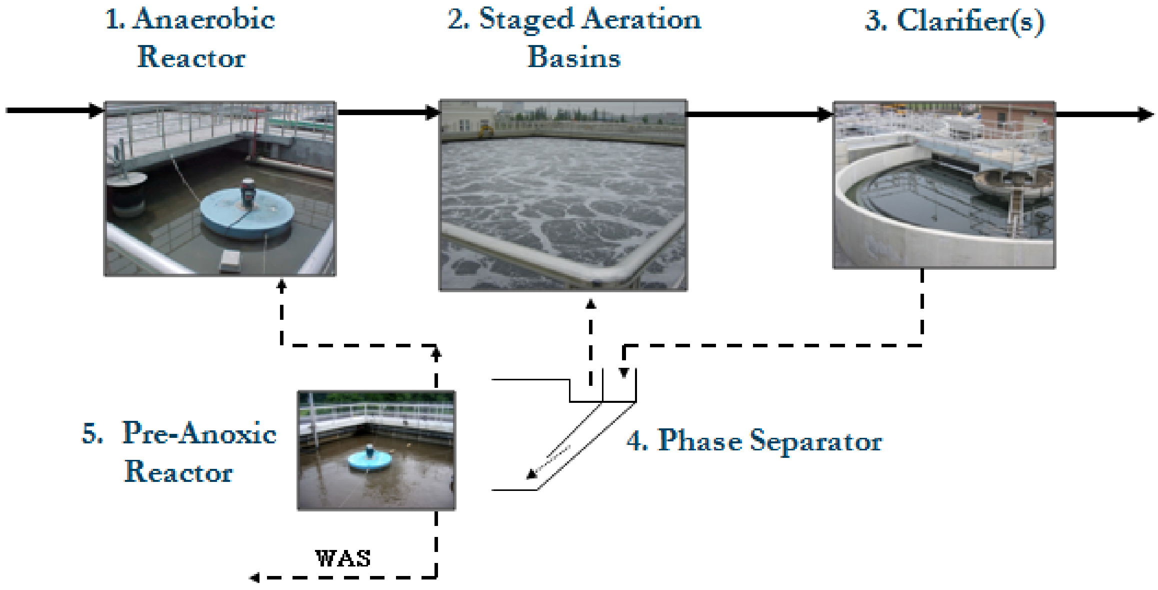

Figure 1. AquaPASS Process flow diagram

The first basin is the anaerobic reactor. This reactor is completely mixed without the introduction of oxygen. Its primary function is to release phosphorous bound to the solids (bacteria) in the recycle flow stream. The released phosphorous will be re-captured in the aeration basin(s). Sludge is conditioned in this basin controlling filamentous bacteria, resulting on improved settling.

Flow exits the anaerobic basin and is equally distributed among the Staged Aeration basins. In addition to recapturing soluble phosphorous, these basins are also responsible for the bulk of carbon removal as well as both nitrification and denitrification.

While some of the carbon is utilized in the anaerobic basin, the bulk of the carbon will be removed in the aeration basins.

Most of the nitrogen entering the plant will be in the form of ammonia (NH_3-N) with the remainder mostly in the form of organic nitrogen (Org-N). Together, the ammonia and organic nitrogen comprise what is referred to as Total Kjeldahl Nitrogen (TKN). In the process, most of the organic nitrogen will be hydrolyzed into the form of ammonia, which will be converted to nitrites (NO_2-N) and nitrates (NO_3-N). The oxidation from nitrates to nitrates occurs very quickly; therefore nitrates will comprise the predominant form of oxidized nitrogen.

The staged aeration basins in the AquaPASS feature the capability of cycling of the aeration. Alternating on/off operation of the blowers will control the dissolved oxygen content within the basin environment. During periods of non-aeration (anoxic reactions), the nitrates will be converted to nitrogen gas (N_2), which will off-gas and reduce the overall nitrogen content of the waste stream.

From the Staged Aeration basins, the flow is conveyed to the clarifiers. This is primarily a gravity separation process where solids settle to the lower region of the clarifier. The surface area of the clarifier is large enough that the higher density of solids can settle against the ambient fluid velocity. The sludge collected in the bottom of the clarifiers is returned back to the process. Comparatively solids-free liquid exits the top of the clarifier for further treatment, typically disinfection.

The phase separator receives the return activated sludge (RAS) from the clarifier. Flow into the phase separator enters an influent trough for uniform distribution across the entire basin width. Flow exits the influent trough via orifices into a baffled compartment that directs the solids towards the basin floor. The basin also is tapered, forming a hopper bottom. The hopper bottom and low discharge location create a circular flow pattern and sludge blanket, which tends to concentrate solids in the lower regions of the basin.

From the bottom of the phase separator, the concentrated sludge is directed to the anoxic basin(s). The remainder of the flow exits over a supernatant weir (with lower concentration of solids) and is directed to the aeration basins. The split ratio is adjustable by the operator, and it is typically set as 70% supernatant return to the aeration basins and 30% concentrated sludge forwarded to the anoxic basin(s).

The anoxic basin is a completely mixed basin where no oxygen is introduced. This is a polishing step before sending the sludge to the anaerobic basin(s). This ensures that the remainder of the nitrates is reduced, and a very low concentration of nitrates is sent to the anaerobic basin for optimizing the effectiveness of phosphorus release.

By recycling the majority of the biological solids while preventing the inclusion of 70% of the associated liquid, the background substrate level in the anaerobic basin is optimized.

Detailed Basin Summaries

Anaerobic Reactor

The anaerobic basin receives raw influent and a recycle flow from the anoxic basin. Flow from the anaerobic basin is sent evenly to each Staged Aeration Basins.

Under normal conditions, the raw influent flow rate will vary up to the maximum specified on the process design. The recycle flow rate is typically pumped from the anoxic basin(s). The target flow rate from the anoxic basin to the anaerobic basin will be 30% of the return activated sludge flow rate, but this percentage is adjustable by the operators.

Flow Summary

- Inflows
  - Raw influent (up to design plant flow rate)
  - Recycle via sludge pumps in the anoxic basin (typically 30% of the return activated sludge flow rate)
  - For design purposes, the recycle flow rate should equal the maximum influent flow rate (assuming a recycle ratio, Q_r/Q_i, equal to 1.0)
- Outflows
  - Uniform flow split to aeration basins

In the Anaerobic Basin wastewater, flow enters in to the basin and the AquaDDM® Direct Drive Mixer is operating. At this point, the AquaDDM mixer is mixing the basin with no aeration in the basin. The D.O. concentration in the basin is < 0.5 mg/l.

6306 N. Alpine Rd. Loves Park, IL 61111-7655 p 815.654.2501 f 815.654.2508 www.aqua-aerobic.com

Figure 2. Anaerobic Basin

Process Considerations:

Influent Combined With Thickened RAS

D.O.= 0 mg/l + <3 mg/l NOx-N

HRT 0.5 – 1.5 Hours

Rapid Mixing

Selector Basin

Bio-P Release

As raw wastewater continues to flow into the anaerobic basin, the completely mixed condition results in the dispersal of the microbial life and the incoming wastewater throughout the basin. In addition, the amount of organic material (as measured by the soluble BOD_5 concentration) present in the reactor increases.

The concentration of Total Kjeldahl nitrogen (TKN) in the basin also increases. The TKN consists of organic nitrogen (Org-N) and ammonia nitrogen (NH_3-N). By the process of hydrolysis (with or without oxygen present), the majority of the organic nitrogen is converted to ammonia nitrogen. The ammonia nitrogen must then be oxidized by the nitrification process. In the presence of oxygen, the nitrification process converts the ammonia nitrogen to nitrate nitrogen (NO_3-N). However, since the influent wastewater has not yet been exposed to an aerobic basin, active nitrification is not occurring.

Due to the absence of D.O. in the anaerobic basin, denitrification is capable of occurring. As a result, the residual level of nitrate nitrogen (if any) that entered this basin from the anoxic basin is depleted to a near-zero concentration level. The denitrification process converts the nitrate nitrogen to nitrogen gas (N_2), and the nitrogen gas is subsequently released to the atmosphere.

The anaerobic basin, in combination with the "non-aerated" periods during the Staged Aeration basin cycling, and the pre anoxic reactor, can be effective in producing an extremely low NO_3-N concentration in the system effluent. However, since the nitrogen that enters the basin is generally not in the form of NO_3-N, the amount of denitrification that occurs in the anaerobic basin is limited to the influent NO_3-N. Since the nitrate is typically low in the influent, a relatively small fraction of the total nitrogen removal requirement is accomplished in the anaerobic basin.

In the anaerobic basin, the effective mixing of the biomass with the influent wastewater in an anaerobic environment results in a substantial release of phosphorus from the cell mass to the liquid medium. This phosphorus is now distributed throughout the entire basin volume. The use of anaerobic conditioning of the sludge mass can be highly effective with respect to improved settling characteristics and controlling the predominance of filamentous organisms in the treatment system.

In summary, this basin is characterized by a completely mixed anaerobic environment in the basin. The basin contains a uniform blend of raw influent wastewater, and sludge from the pre anoxic basin. The environment is classified as anaerobic with D.O. concentrations at or near zero. In essence, this basin is utilized for denitrification, biological phosphorus release, and conditioning of the sludge mass.

Staged Aeration Basins

Each Staged Aeration basin receives flow from the anaerobic basin and the supernatant from the phase separator. In the Staged Aeration basins, wastewater enters the basin from the anaerobic basin, and the air supply system begins delivering oxygen to the basin. The AquaDDM mixer continues to operate, and the completely mixed environment is maintained. The introduction of oxygen converts the basin from an anoxic environment to an aerobic environment. Since the AquaPASS was designed to achieve nitrification and denitrification, the aeration system is cycled on and off in the Staged Aeration basin. This alternately creates aerobic and anoxic conditions.

Nitrification occurs during the aerated periods of operation, and denitrification occurs during the non-aerated periods of operation. Although BOD_5 reduction normally occurs under aerobic and anoxic conditions, the rate of BOD_5 reduction is much greater during the aerated periods of operation. A schematic of the Staged Aeration basin phase of operation is shown in Figure 3.

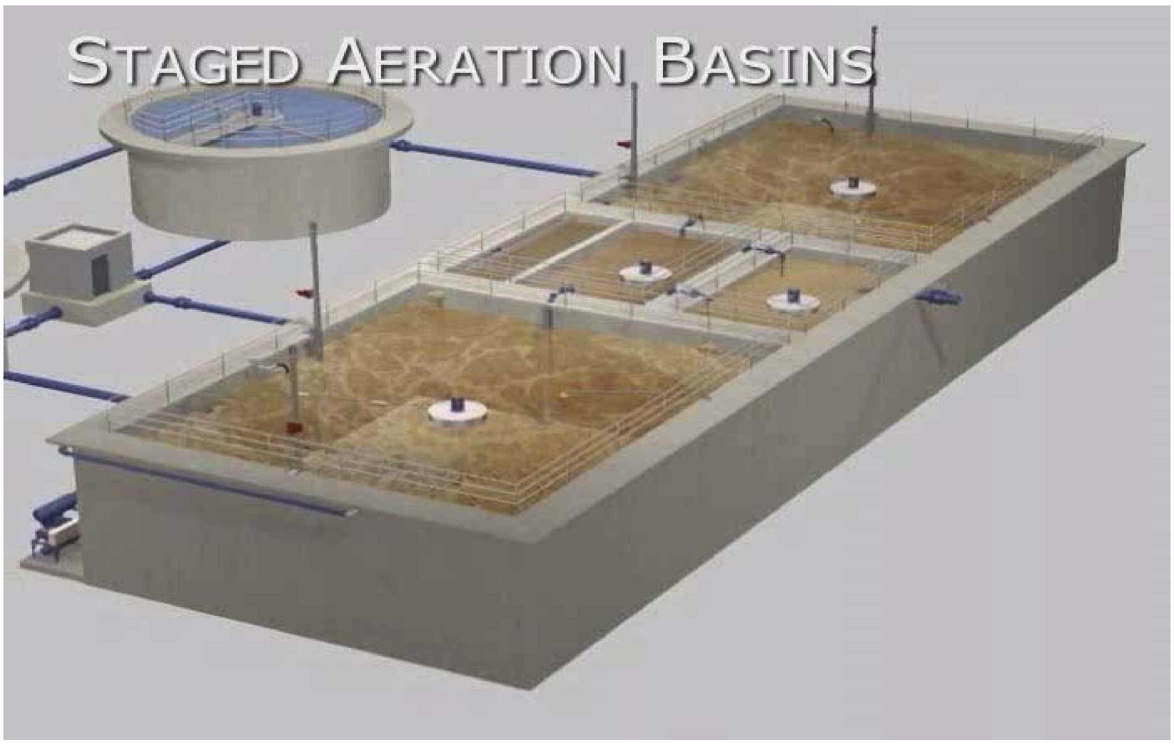

Figure 3. Staged Aeration Basins

Process Considerations

The Staged Aeration basins feature multi-level aeration management. The time of each event per hour can be 30 – 50 minutes for the aeration stage and 10 -30 minutes for the anoxic stage. The optimal DO levels during aeration stage is 2 mg/l and during the anoxic stage < 0.2 mg/l.

Typical:

Dedicated Aerobic Fraction = 45/60 = 75% = 18 hours/day

Dedicated Anoxic Fraction = 15/60 = 25% = 6 hours/day

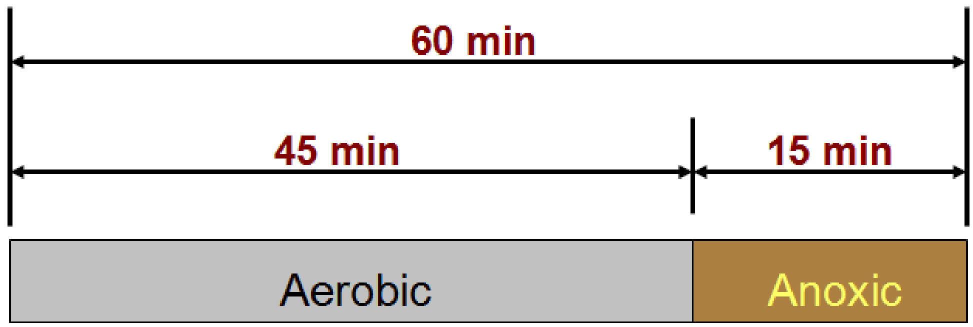

Figure 4. Stage Aeration Basin hourly aeration cycles example

Flow Summary

- Inflows per basin

  Roughly 65% of plant flow from the anaerobic basin (0.5 plant flow and 0.15 recycle via the anoxic basin)

  Roughly 35% of plant flow from the phase separator in the form of supernatant drawn from the top of the phase separator

- Outflows per basin

  Roughly 100% of plant flow to clarification

  During periods of low plant flow, submersible sludge pumps may pump from the aeration basin to the phase separator

The wastewater that has entered, and continues to enter the basin represents a certain potential oxygen demand. The oxygen demand is due to the aerobic metabolism of the organic constituents (i.e. BOD_5 reduction) and the nitrification of NH_3-N. The aeration system has been sized to meet this oxygen demand.

The dissolved oxygen (D.O.) concentration profile in the basin will normally reveal a pattern of increasing D.O. concentration during the aerated periods, followed by decreasing D.O. concentration (to near-zero) during the non-aerated periods. In other words, the D.O. concentration will reach a peak value at the end of each aeration period.

The concentration of total nitrogen present in the basin will typically remain low in the Staged Aeration Basins due to the On/Off sequencing of the aeration system. The nitrification and denitrification processes typically reduce total nitrogen concentrations in the basin as the raw waste flow continues to enter the basin with additional nitrogen. In other words, the rates of nitrification and denitrification are typically more than sufficient to offset the rate of nitrogen entering the basin.

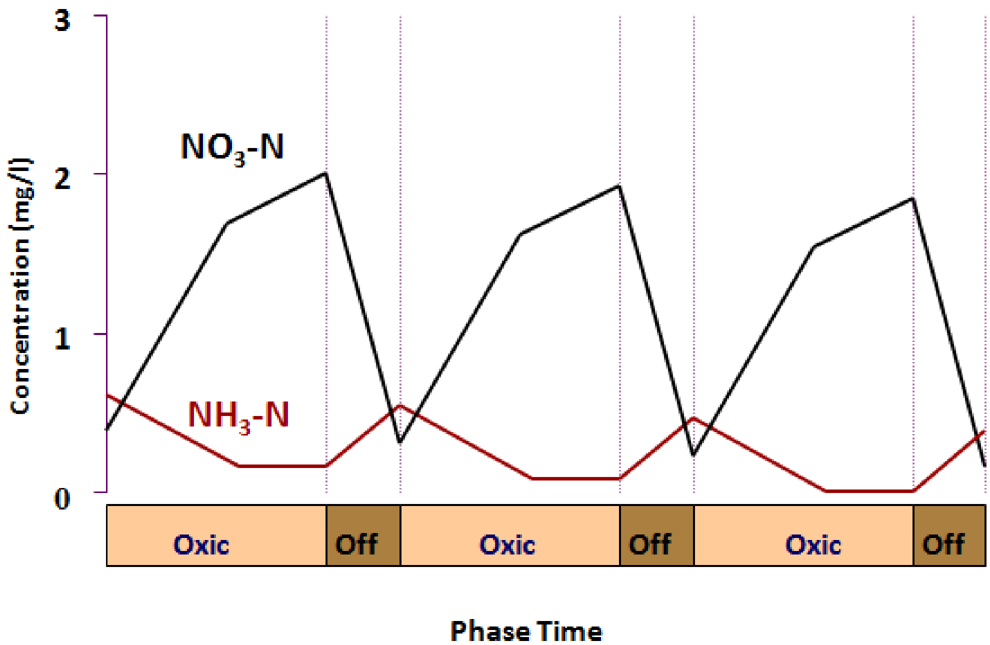

Figure 5. Staged Aeration Basins multi-level aeration for nitrogen removal

Nitrification is a two-step process involving two individual groups of microorganisms, namely *Nitrosomonas* and *Nitrobacter*. This process does not remove nitrogen from the wastewater. It merely converts it from one form of nitrogen to another form of nitrogen. In the presence of oxygen, ammonia nitrogen (NH_3-N) is first converted to nitrite nitrogen (NO_2-N) by the *Nitrosomonas*. The nitrite nitrogen is then converted to nitrate nitrogen (NO_3-N) by the *Nitrobacter*. Since the *Nitrobacter* are generally much faster "workers" than the *Nitrosomonas*, the NO_2-N concentration in the basin is usually negligible.

Nitrogen is actually removed from the wastewater by the denitrification process. Denitrification is performed by a broad range of microorganisms, collectively known as "heterotrophs", that are present in most wastewater treatment systems. In the absence of oxygen, these heterotrophs convert nitrate nitrogen to nitrogen gas (N_2). The nitrogen gas is subsequently released from the basin into the atmosphere.

The amount of soluble organic material (as evidenced by the BOD_5 concentration) in the basin will typically be low in the Staged Aeration Basin. In this basin, biological oxidation occurs simultaneously with the addition of organic material to the basin. The decline in BOD_5 concentration will closely parallel the pattern observed for the total nitrogen concentration.

As wastewater enters the Staged Aeration basin, the onset of aerobic conditions in the basin allows the microorganisms to "take in" phosphorus. Therefore, the phosphorus that was previously released into solution in the anaerobic basin is now taken back into the cell mass. The phosphorus present in the influent is also taken in by the biomass. Since the microorganisms were previously "depleted" of phosphorus, they have a tendency to take in more phosphorus than the amount that is necessary to meet their nutritional requirements. The term used to describe this phenomenon is "enhanced biological phosphorus removal". The anoxic periods present in the Staged Aeration basins are not long enough to allow a re-release of phosphorus from the biomass into the liquid medium. Therefore, the effluent from the basin will contain a low concentration of total phosphorus.

Effluent quality parameters will provide the operator with a basis for determining the necessity of adjusting the aeration on/off cycle structure. In summary, the Staged Aeration Basins are tanks that are always in a completely mixed condition that alternates between an aerobic and anoxic environment.

Phase Separator

The phase separator has the most activity going on hydraulically, yet has no moving parts. In normal operation it will receive a flow rate roughly equal to the plant flow in the form of return activated sludge from the clarifiers. Under low flow conditions, it may receive a recycle stream from submersible pumps in the aeration basins.

This flow will enter an influent trough. The influent trough will have a series of orifices for distributing the flow across the entire basin width. Upon leaving the influent trough, the flow is constrained from entering the main basin until it has traveled roughly 1/3 toward the bottom of the basin. This directs the flow towards the bottom of the basin and promotes a slow, circular flow pattern that helps maintain the sludge blanket integrity.

Flow exits the basin in two manners. The heavier, settled particles are sent to the anoxic basin. This typically represents 30% of the inflow to the phase separator. The remaining flow must exit over a supernatant weir, into a supernatant trough for return to the aeration basins.

The pumping rate out of the anoxic basin determines the water level in the phase separator, and ultimately the flow split between the anoxic and aeration basins.

Isolation of flow entering the phase separator requires nothing more than turning off the pumps feeding it. There will be no means to isolate the phase separator from the anoxic basin. Isolation of an aeration basin will be achieved by moving the divider plate than normally splits surface flow to the applicable end of the effluent trough, where it will act as a manual slide gate to the offline aeration basin.

Flow Summary

- Inflows

  Return activated sludge from the clarifiers, roughly equal to flow rate entering the plant.

- Outflows

  Underflow of heavier particles and liquid to the anoxic basin via openings at the base of the wall between the two basins, operator adjustable but typically 30% of flow into the phase separator. May range from 0% to 100%.

  Surface flow over a supernatant weir, into a supernatant trough, divided in the center to supply equal flow to each aeration basin. Determined by the amount of flow pumped from the anoxic basin, typically 70% of flow into the phase separator. May range from 0% to 100%.

- Inflow isolation not required

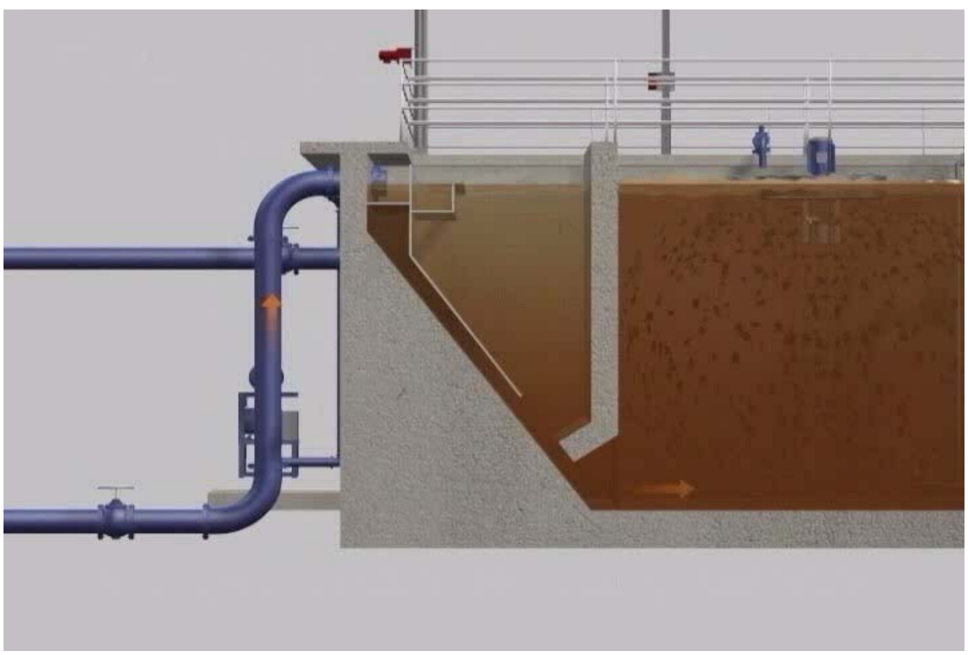

Figure 6. Phase Separator

Process Considerations

RAS from Final Clarifier

Typical HRT 0.5 Hours

RAS Concentrated 20 – 50 %

Supernatant Transferred to Staged Basins

Thickened Sludge to Pre-Anoxic Basin

Anoxic Basin

The anoxic basin receives recycle flow from the phase separator. Under normal operating conditions this will be approximately 30% of the plant flow rate, though it is operator adjustable and may vary from 0 to 100% of the plant flow rate. All flow exits this basin is typically pumped. Since all flow enters this basin via the phase separator, which receives flow from return activated sludge pumps, and all flow is pumped out of the basin, no method of isolation is required.

Figure 7. Anoxic Basin

Flow Summary

- Inflows

  All sludge from the phase separator enters the anoxic basin. Typical flow will be 30% of the plant flow rate, but is operator adjustable and may range from 0 to 100% of the plant flow rate.

- Outflows

  Under normal operation all flow is pumped to the anaerobic basin.

  Waste sludge is typically pumped out from this basin

Process Considerations

Thickened RAS from Phase Separator

Typical HRT 0.5 – 1.5 Hours

NO3-N Reduced Prior to Anaerobic Basin

Internal Recycle Rates 15 – 30 % of Influent Flow

Waste Sludge

AquaPASS systems, like other activated sludge process variations, are dependent upon the development of a mixed culture of bacteria and other microbial life forms to accomplish treatment objectives. As a result of the biological degradation of organic matter and the accumulation of inert material present in most wastewaters, it is necessary to discharge certain quantities of solids from the basins in order to maintain an appropriate concentration of mixed liquor suspended solids (MLSS) in the system, and to control the sludge age.

The programmable logic controller (PLC) has been programmed to initiate the Waste Sludge operation. Waste sludge will be pumped at an operator adjustable period of time from the Anoxic basin in order to control the system MLSS concentration.

Secondary Clarifiers

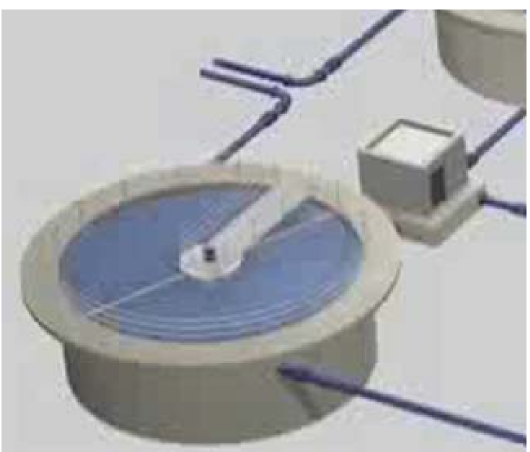

Figure. 7 Secondary Clarifier

Flow from the Staged Aeration Basins is sent to the clarifiers. Solids settle to the bottom of the clarifier and sent back to the phase separator basin, while floatable material or scum is removed mechanically on the surface. The clear liquid (treated water) or supernatant exits the basin through an effluent weir, typically a v-notch weir.

6306 N. Alpine Rd. Loves Park, IL 61111-7655 p 815.654.2501 f 815.654.2508 www.aqua-aerobic.com