

Coupling Trickling Filter or RBC's with Activated Sludge

By

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1. What are Combined or Coupled Plants?

Most coupled or combined processes use a fixed film reactor in series with a suspended growth reactor. In combined processes, the fixed film reactor usually consists of a biological tower. The suspended growth reactor is generally an aeration basin or small contact channel. Other types of combined processes have been used where rotating biological contactors (RBC's), lagoons, or other treatment processes are in series with biological towers. Combined processes have been described by various names such as two-stage, series, coupled, or dual processes.



Big Picture View from top of a Biological Tower

Commonly used combined processes range between two groups: those that have low, organic loading (at one extreme), to fixed film reactors with high (roughing) organic loads. Table 1 presents an overview of the trickling filter categories, total organic loading (TOL) and types of media. The most common types of combined process involve trickling filters (or biofilters) and aeration basins (or contact channels) as shown in the schematics in Figure 1. Figure 1 illustrates how process modes can change by varying the (1) place at which return activated sludge (RAS) enters the system, (2) location of the reaeration tank, and (3) the use of intermediate clarifiers.

Activated Biofilter. The activated biofilter (ABF) process uses a fixed film reactor that treats low to moderate organic loads. High-rate plastic or redwood media must be used in the ABF fixed film reactor (rather than rock) because return sludge is incorporated with the primary effluent and recycled over fixed film media. Some designers have

concluded that improved sludge settleability occurs with ABF when biological solids are incorporated with the primary effluent before distribution to the fixed film reactor. One theory of why the benefit (lower SVI's) occurs is that the high F:M ratio and plug flow of the filter allows heterotrophic bacteria to be more competitive than filamentous bacteria. A similar observation has been made with the use of selectors (oxic, anoxic, and anaerobic) and pure oxygen activated sludge.

Trickling Filter Solids Contact. The trickling filter solids contact (TF/SC) process generally includes a fixed film that has low to moderate organic loads followed by a small contact channel. The contact channel is generally 10 to 15% the size normally required for an aeration basin for activated sludge alone. By combining the fixed film reactor with the contact channel, the fixed film reactor size is reduced by 10 to 30% of

that normally required if treatment had been accomplished with solely a TF process. Benefits of the TF/SC process stem from low power requirements (due to a relatively high dependence on the TF) to remove most of the soluble BOD. Other benefits include the ability to upgrade existing rock TF's through polishing the fixed film effluent using return activated sludge as a bioflocculating agent.

Roughing Filter Activated Sludge. A common method of upgrading existing activated plants is to install a roughing filter ahead of the activated sludge process. As part of the roughing filter activated sludge (RF/AS) process, the roughing filter is generally 12 to 20% of the size required if treatment had been accomplished through the use of the trickling filter process alone. Hydraulic retention time in the aeration basin is generally 35 to 50% that required with the use of the activated sludge process alone. Both the

Table 1

TRICKLING FILTER USE IN COMBINED SYSTEMS

Filter Classification	Categories			
	Low	Intermediate	High	Roughing
Filter Total Organic Load (TOL) (lb BOD/d/1000 cu ft)	<25	25 - 40	40 - 100	100 - 300
Filter Media ^a	Rock or High Rate	Rock or High Rate	Rock or High Rate	High Rate Vertical
Nitrification ^b	Yes	Partial	Unlikely	No
Need for a Combined Process to make Limit				
Secondary Treatment	No	Unlikely	Likely	Yes
Advanced Treatment	Yes	Yes	Yes	Yes
Process Choice (Typical)	TF/SC ABF	TF/SC ABF	TF/SC TF/RBC 2-Stage Filters	TF/AS RF/AS BF/AS 2-Stage Filters

Notes

a High Rate = plastic or redwood

b At 20 deg. C and without a second stage or combined process

Legend

ABF Activated Biofilter
TF/SC Trickling Filter Solids Contact
RF/AS Trickling Filter Activated Sludge
BF/AS Biofilter Activated Sludge

TF/SC and RF/AS processes have the same process schematic. However with RF/AS, a much smaller TF is used so that the aeration basin must provide a significant amount of oxygen, BOD removal, and solids digestion. This differs from the TF/SC process where the TF is larger and provides almost all of the SBOD treatment, allowing the contact channel to provide only enhanced solids flocculation and effluent clarity. A deciding consideration in process selection is often the availability of existing treatment units that influence the balance between new unit size and available capital.

Biofilter Activated Sludge. The biofilter activated sludge (BF/AS) process is similar to that of RF/AS except that with BF/AS, return activated sludge (RAS) is recycled over the fixed film reactor, similar to the recycle of the ABF process. Incorporating RAS recycle over the fixed film reactor has sometimes reduced sludge bulking from filamentous bacteria, especially with food-processing wastes, which are difficult to treat. Although it has sometimes improved sludge settleability, there is no evidence that sludge recycle improves the oxygen transfer capability of the biological filter.

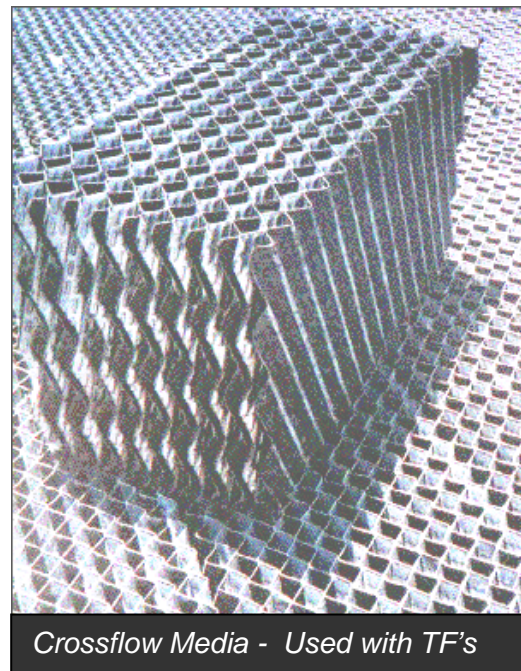
Trickling Filter Activated Sludge. The trickling filter activated sludge (TF/AS) process is designed for high organic loads similar to those of RF/AS or BF/AS. However, a unique feature of TF/AS is that an intermediate clarifier is provided between the fixed film and suspended growth reactors. The intermediate clarifier removes sloughed solids from the fixed film reactor before the underflow enters the suspended growth reactor. A major benefit of using the TF/AS mode of combined process is that solids generated from carbonaceous BOD removal can be separated from second-stage treatment. This is often a preferred mode where ammonia removal is required and the second stage of the process is designed to be dominated by nitrifying microorganisms. Another advantage in using intermediate clarification is reduced effects from sloughing of the fixed film on the suspended growth portion of the plant. The term "TF/AS" has also been used to describe TF/SC processes where no intermediate clarifier exists but the suspended growth hydraulic residence time (HRT) is near or greater than 2 hours. Two hours HRT has generally been considered the point where the suspended growth reactor is being used for conventional aeration and for more than bioflocculation purposes.

2. Who has Combined Wastewater Plants and Why?

Many combined plants naturally spring from existing facilities that have previously had only one biological process. Combining or coupling processes is an attempt to strengthen treatment without casting aside existing-single processes. For existing trickling filter plants the upgrade to trickling filter solids contact is often selected to take advantage of the trickling filter unit already in place. Roughing filter-activated sludge is often selected to upgrade existing activated sludge plants to take advantage of the large basin that already exists. Regardless of the type of process chosen, the key is to maintain an adequate balance and relative size of biological units to obtain the desired results. Table 2 provides an overview of combined processes in qualitative terms (F:M, MCRT, HRT, etc.) considered appropriate for most treatment applications.

The use of combined biological processes has become increasingly popular. This increase is largely because of attempt the need to minimize weaknesses of individual systems within a limited budget. For example, fixed film processes are known for their ability to resist shock loads, energy efficiency, and low maintenance. By combining a shock-resistant fixed film reactor, with a suspended growth process known for producing high-quality effluent the combination can result in treatment that highlights the best of the two parent processes. Conversely, a weakness of the activated sludge processes is often considered to be its need for close operator attention. Preceding an activated sludge process with a biofilter may result in a more forgiving system that is easier to operate.

Finally, RBC processes tend to become oxygen limited and easily overloaded in the first stages. Pretreating primary effluent first in a roughing filter has been one means of eliminating oxygen transfer problems with RBCs.



Crossflow Media - Used with TF's

Despite the positive features of a combined plant, there may also be disadvantages or added challenges. The following provides information on special considerations or potential disadvantages of combined processes.

Primary Clarification: Studies have shown that both the amount and nature of suspended solids in the primary effluent can greatly affect the performance and solids yield from combined processes. The effect will vary, depending on the type of filter media used in the first-stage process. The use of rock filter media tends to reduce the effects of high suspended solids in the primary effluent because produced and incoming solids are retained considerably longer in the small void space associated with rock media. The added solids retention allows anaerobic digestion and solids reduction to occur. Both the amount and characteristics of primary solids can greatly affect design choices for combined processes.

Energy: Designers generally consider that biological treatment with fixed film reactors requires 25 to 50% of the energy of suspended growth systems. However, with the emergence of fine bubble diffused air, plus good suspended growth design, many design evaluations show the energy gap between fixed film and suspended growth reactors is narrowing. With combined processes, one study indicated that the energy savings with either fixed film or combined-process operation was not realized because

of the poor turndown of equipment. Generally, high power rates will tend to favor combined processes that have large fixed film reactors (ABF or TF/SC processes).

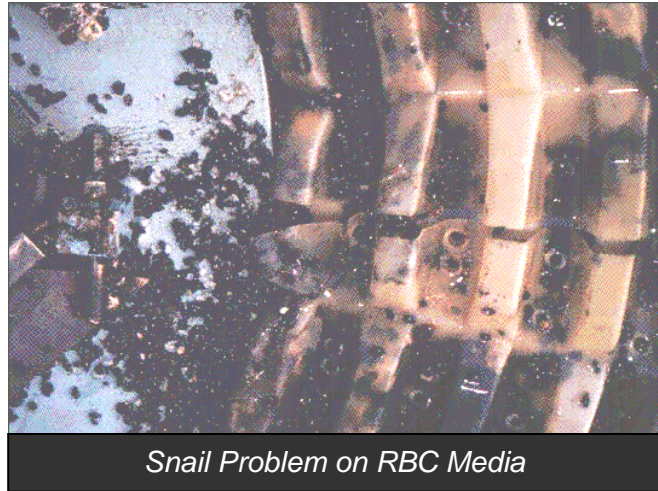
Solids Recycle: A number of pilot studies have indicated that recycling biological solids over the fixed film reactor may improve sludge settleability. However, there is no evidence that shows sludge recycle will aid oxygen transfer or reduce the size of the second-stage suspended growth reactor. Sludge recycle has been used extensively in the treatment of food-processing waste in both the ABF and BF/AS combined-process modes. Sludge recycle has been used extensively with horizontal, redwood media as a means of increasing its relatively low surface area in comparison with plastic media. Sludge recycle use with vertical, plastic media is limited but has shown to sometimes provide the same improved sludge-settling characteristics as achieved when applied with redwood media. Sludge recycle has been reported to increase odors at some facilities.

Nitrification: Requirements to achieve nitrification often sway process economics toward suspended growth, rather than to fixed film or combined processes. This is especially true where cold water temperatures prevail, resulting in a correspondingly greater reduction in activity for nitrifying bacteria than for BOD-removing heterotrophic bacteria. Design techniques often used to encourage nitrification for combined processes include using an intermediate clarification between the first and second stages. Another approach is the use of solids reaeration. Solids reaeration generally provides two to four times more mean cell residence time per unit of aeration volume than does contact through a conventional aeration basin or channel.

Odor: Nuisance due to odors tends to be more severe with fixed film than with suspended growth reactors. Most combined processes are free from nuisance-type odors but the design engineer should, nonetheless, carefully consider the possibility of odor problems. If odor problems are occurring in the headworks or primary clarifiers, then odor control should be a significant design consideration for the fixed film reactors in combined processes. Most odor problems occur where plants have industrial loads or inorganic constituents (nitrogen or sulfur) that tend to be odor producing. Evidence indicates that odors result from waste characteristics and the presence of high percentages of certain industrial wastes. Stated differently, fixed film reactors used in combined processes with low to moderate loading can generate as much odors as can combined processes with heavily organically loaded fixed film reactors. If odors become a problem, (1) waste characteristics, (2) poor hydraulics, or (3) lack of ventilation often cause them.

Sloughing: Natural biological sloughing that occurs from fixed film reactors can be controlled (at least to a limited degree) by varying the hydraulic wetting rate to the fixed film reactor. Surveys indicate that combined processes with small suspended growth reactors (ABF or TF/SC) tend to be more susceptible to variations in MLSS than are combined processes with large suspended growth reactors (RF/AS or BF/AS).

Snails. Combined processes differ from conventional TF application in that snails can often settle in transfer structures or aeration channels with low energy for mixing. Care should be exercised in maintaining adequate mixing and minimizing the possibility of the deposition of snail cases in unmixed areas of containment structures. Some designers include a low velocity flow transfer box between the fixed film and suspended growth reactor to encourage the settling and removal of snails.



Snail Problem on RBC Media

Produced Solids. Deciding how to use an existing rock TF may depend on the amount of produced solids in the biological treatment process. Depending on the organic and hydraulic loading, produced solids from rock media generally range from 0.4 to 0.7 lb TSS/lb BOD (lb produced solids/lb primary effluent BOD). With the use of plastic or redwood media, the amount of solids digestion and effective mean cell residence time (MCRT) is greatly reduced because retention is less than that with rock media. Consequently, solids production with synthetic media often ranges from 0.8 to 1.0 lb TSS/lb BOD, even when a combined process is used. The amount and character of solids in the primary effluent can also greatly affect both the settling characteristics and solids production from a combined process.

Phosphorus Removal: Phosphorus removal by chemical means is compatible with all types of combined processes. In fact, chemical addition to the primary clarifiers almost always improves performance and therefore results in lower organic loading to the trickling filter. However, all combined processes, with the exception of

activated biofilter, present an obstacle to biological phosphorus removal. The reason for difficulties in achieving biological phosphorus removal is the difficulty in placing an anaerobic selector in front of the fixed film reactor. The problem often comes from concerns of media plugging, especially with rock type filter media. To overcome this, the flow schematics illustrated in Figure 2 have been used.



Mixer used for anoxic selector

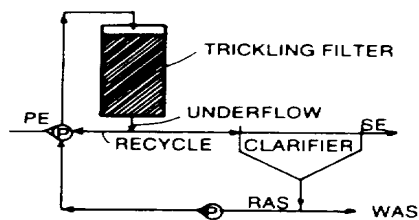
Flow Schematics Combined Processes

FIGURE 1

PROCESS FLOW DIAGRAMS

(A) ABF

The activated biofilter (ABF) process has no aeration basin. A mixed liquor is created by recycling biological solids from the secondary clarifier to the top of the filter.

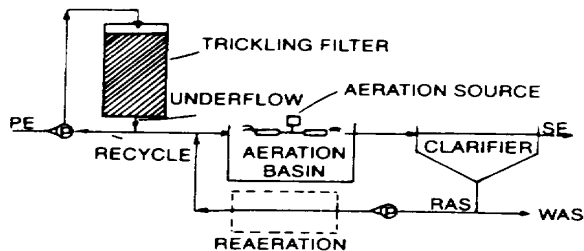


(a)

(B) TF/SC &

RF/AS

Trickling Filter Solids Contact (TF/SC) consists of a trickling filter followed by a short (less than 2 hrs) retention in an aeration basin. With TF/SC produced secondary solids are returned to the aeration basin rather than to the filter and filter loading is less than 100 lb BOD/d/K cu ft.

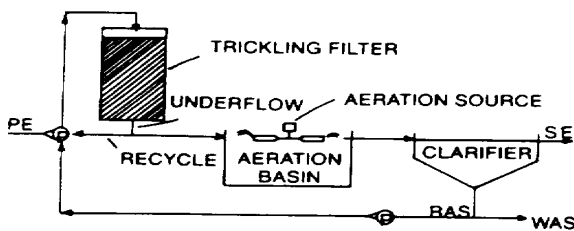


(b)

Roughing Filter Activated Sludge (RF/AS) is similar to TF/SC except that the aeration time is larger than 2 hrs and filter loading may be high.

(C) BF/AS

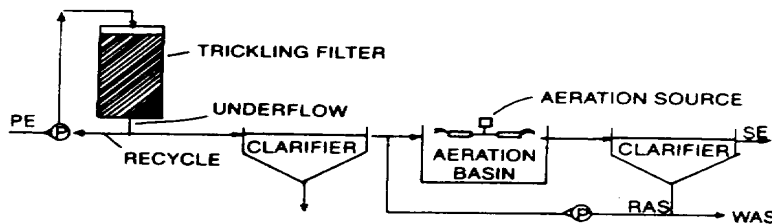
Biofilter Activated Sludge (BF/AS) consists of a filter with recycle or RAS to the top of the filter. The filter is followed by either an aeration basin or contact channel.



(c)

(D) TF/AS

Trickling Filter Activated Sludge (TF/AS) has traditionally been used by designers to indicate that an intermediate clarifier exists so that a traditional TF is preceding an AS plant. However the term TF/AS is also often used to describe a TF/SC process that has aeration times near or exceeding 2 hrs.

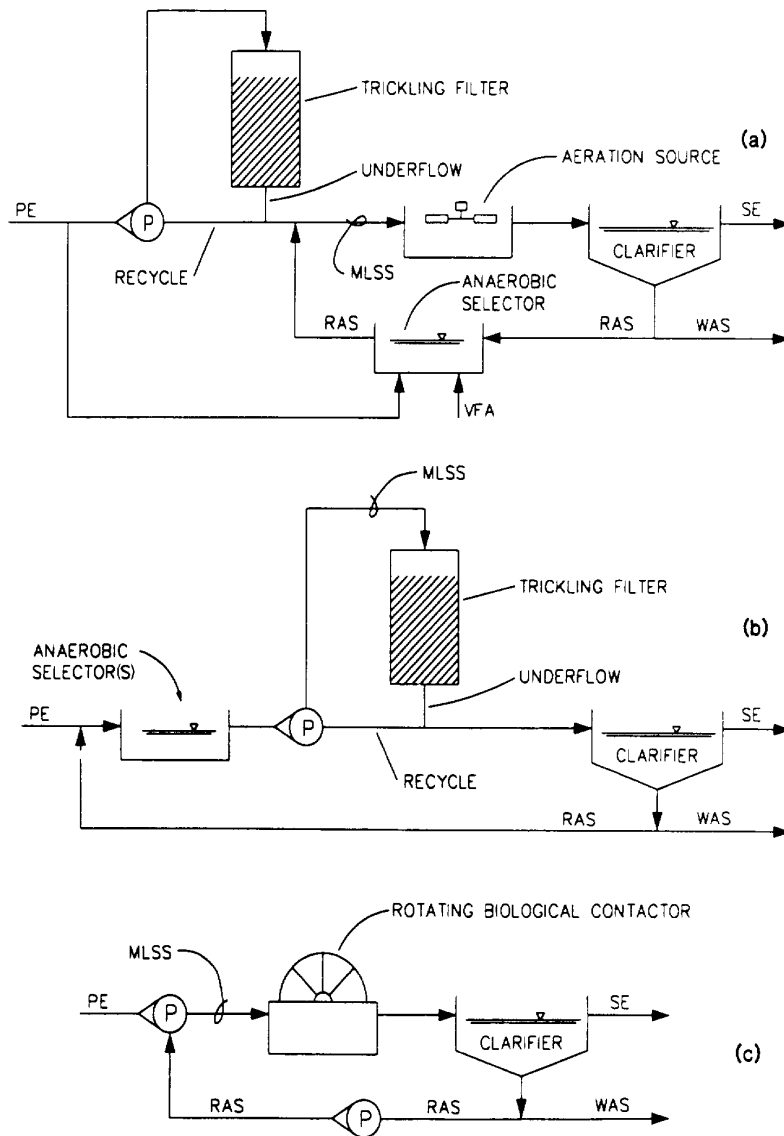


(d)

Enhanced Combined Processes

FIGURE 2

PROCESS DESCRIPTION



(A)

SIDE STREAM ANAEROBIC SELECTOR

A side-stream selector in the RAS may be used to provide enhanced biological phosphorus removal where "rock" filter media exists. To create an anaerobic environment it is necessary to add a volatile fatty acid (VFA) source to the RAS. Check patent issues before applying.

(B)

MAIN STREAM ANAEROBIC SELECTOR

A selector in the main flow stream may be used with plastic or horizontal media to encourage biological phosphorus removal. This variation of a combined process is similar to many suspended growth BNR flow schemes. Note: Attention must be paid to media strength and operating weight on plastic media..

(C)

ACTIVATED RBC

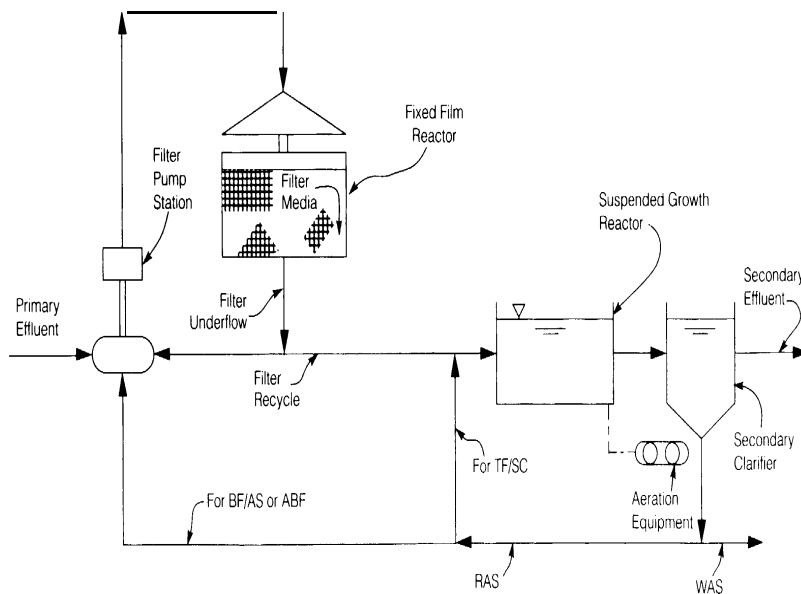
Another selector process can be achieved by recycling RAS to the 1st stages of an RBC. This process has been known to provide added biofloculation and improve effluent quality.

Several plants have either preceded or followed the RBCs with additional suspended growth aeration. These steps can aid in improving sludge settleability and in achieving nitrification.

Englewood, Colorado Activated Sludge Upgrade

FIGURE 3
FACT SHEET

PROCESS FLOW DIAGRAM



Upgrade Consideration: The Littleton Englewood Wastewater Treatment plant's activated sludge plant was reaching its design capacity. In addition ammonia nitrogen limitations had been imposed.

What was done? A plastic media roughing filters was added ahead of the activated sludge basins. To achieve nitrification, nitrifying filters (with no clarification) were added after the secondary clarifiers but before disinfection. Fine bubble diffusers were added to all 5 aeration basins.

How has the Facility performance been effected? The roughing filters are now taking load off of the activated sludge basins. All basins are in operation until additional filter capacity can be added.

Is the Combined Process easy to operate? The combined plant requires less process control than a conventional activated sludge plant. The plant is controlled at a 1.7 to 2.0 day MCRT.

ADVANTAGES

- Reduced waste load of solids to the solids handling system..
- Plant was expanded with relatively small foot-print..
- Ease of Operation..
- Less floatables on secondary clarifier.
- Improvement in secondary effluent quality by 5 to 10 mg/L.

DISADVANTAGES

- Odor control needed including covering filters and scrubbing of air.
- Additional pumping cost to filters.

UNIT SIZES AND LOAD

Trickling Filter
Number = 1
Dia. = 105 ft
Media Height = 16 ft
Media Type = Crossflow

Contact Channels or Basins
Basins Operated = 5
Total Basin Vol = 2.6 MG

Plant
Flow = 26 mgd
Pri Eff BOD = 150 mg/L

Unit Loadings
Filter TOL = 235
Basin HRT = 2.4 hrs

Effluent Quality
BOD = 10 to 15 mg/L

Corvallis, Oregon Trickling Filter Upgrade

FIGURE 4

FACT SHEET

PROCESS FLOW DIAGRAMS

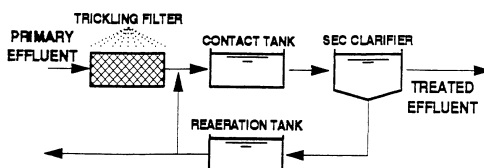
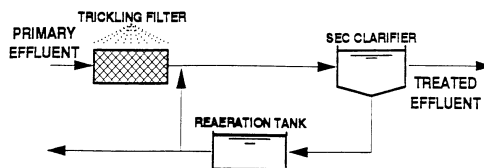
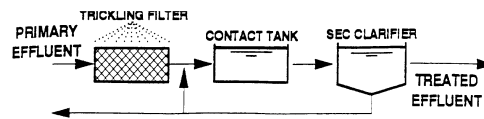
Upgrade Considerations: The Corvallis Wastewater Treatment Plant's rock trickling filters were reaching their design capacity. In addition more stringent BOD standard were being imposed.

What was done? Activated sludge basins were added after the rock filters. In addition there was added a small transfer channel that later served as a reaeration tank. The plant can operate as either TF/SC or TF/AS. A major improvement also included the addition of secondary clarifiers with 18 ft water depth. The Plant is currently operating in the TF/AS mode and during summer months is operated with one aeration in service, with half of the basin operated as an anoxic selector (mixing with no aeration).

How has the Facility performance been effected? Effluent quality is always under 10 mg/L BOD and TSS.

Is the Combined Process easy to operate? The combined plant requires less process control than a conventional activated sludge plant. Process control consists of maintaining desired MLSS and there is no need to track MCRT.

What would be done differently? Provisions would be made for some bypass of primary effluent around the primary clarifier to encourage denitrification.



ADVANTAGES

- A key to successful operation is the 18 ft deep secondary clarifiers.
- Resistance of the trickling filter to shock loads.
- Low sludge yield and ability to gravity thicken to 4% solids.
- Little or no process control required. Changing in wasting necessary about every two months.

DISADVANTAGES

- The TF is very dominant. Whatever happens on the filter controls the system.
- Filter debris (snails, worms, etc) must be removed in gravity sumps or in the secondary clarifier.

UNIT SIZES AND LOAD

Trickling Filter
 Number = 2
 Dia. = 160 ft
 Media Height = 8 ft
 Media Type = Rock

Contact Channels or Basins
 Number Channels = 1
 Basins Operated = 1
 Basin Volume = 0.673 MG

Plant
 Flow = 8.5 mgd
 Pri Eff BOD = 138 mg/L

Unit Loadings
 Filter TOL = 30
 Basin HRT = 1.9 hrs
 Channel HRT = 15 min

Effluent Quality
 BOD = 5 mg/L

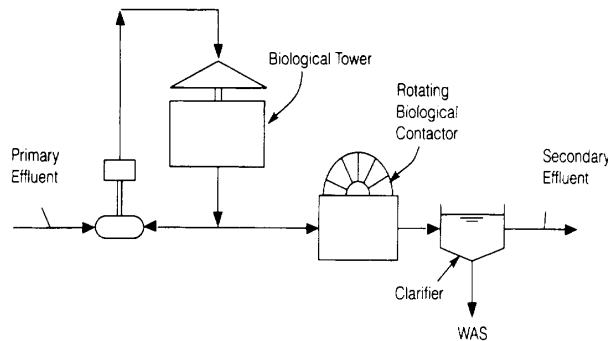
Kirkville, Missouri RBC Upgrade

FIGURE 5

FACT SHEET

PROCESS Discussion

Upgrade considerations: The Kirkville Wastewater Treatment plant's mechanical drive RBC's were being overloaded by dairy waste. The first stages of the RBC's were white with Beggiatoa growth. Treatment performance was poor and several shafts had become overloaded and broke due to excess weight.



What was done? A 65 ft dia. plastic media trickling filter was added ahead of the RBC's and supplemental air was to the first state of the RBC's .

How has the Facility performance been effected? The RBC's are now nitrifying and are serving as advanced treatment units. There no sign of Beggiatoa or organic overload on the RBC's. Shaft breakage has not been a problem.

Is the Combined Process easy to operate? The plant requires no process control. The only added maintenance is removal of snails from the RBC's. The RBC's had no snails until the trickling filter was added

What would be done differently? Provisions would be made for some bypass of primary effluent around the biological tower. Drains would be placed in the RBC units to facilitate the flushing out of snail cases.

ADVANTAGES

- Eliminated organic overload on RBC's.
- Requires no process control and little maintenance.
- Results in good ammonia removal except during high flows.

DISADVANTAGES

- Snail Problems require shut down of RBCs every 3 years followed by manual removal of snails.

UNIT SIZES AND LOAD

Trickling Filter
Dia. = 65 ft
Media Height = 14 ft

RBC Units
Number Trains = 5
Number Shafts = 20
1st stg = 760 K sq ft

Plant
Flow = 2.1 mgd
Pri Eff BOD = 168 mg/L

Unit Loadings
Filter TOL = 63
RBC 1st stg SOL = 2.6
RBC system SOL = 1.3

Effluent Quality
BOD = 11 mg/L
Ammonia = 2 mg/L