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Project Summary

Trickling Filter/Solids Contact Process: Full-Scale Studies

Raymond N. Matasci, Arthur H. Benedict, and Denny S. Parker

This report outlines the characteristics that distinguish the trickling filter/solids contact (TF/SC) process for municipal wastewater treatment from other similar processes. The SC feature provides a short aerobic contact period between the TF effluent and the recycled underflow solids from the secondary clarifier to promote solids capture and produce a final effluent with a low suspended solids concentration.

The report also summarizes the results of field studies at TF/SC facilities in Oconto Falls, Wisconsin; Tolleson, Arizona; Medford, Oregon; and Chilton, Wisconsin. These studies and a review of historical operating records at these plants and at Corvallis, Oregon (where the process was first successfully demonstrated in 1979), provide additional insight into the performance of the TF/SC process under different design and loading conditions.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In certain circumstances, the trickling filter/solids contact process (TF/SC) for municipal wastewater treatment may qualify for funding as innovative technology; but more information is required about the design and performance of this process. The objectives of this study were therefore as follows:

1. To develop a definition of the TF/SC process that distinguishes it from other similar processes
2. To document the design and performance information available from existing TF/SC facilities, and
3. To conduct special field investigations to provide additional insight into the TF/SC process. The project was not intended to produce a design manual, since field investigations and operating data were limited.

Process Characteristics

TF/SC is a biological and physical process that includes (1) a TF, (2) an aerobic solids contact period, (3) a flocculation period, and (4) secondary clarification. Two operating features are also important: Solids must be maintained in an aerobic flocculant state, and solids are recycled from the secondary clarifier to combine with TF effluent as a mixed liquor.

The primary function of the first element in the TF/SC process, the TF, is to reduce the soluble BOD in the wastewater. The aerobic solids contact period is then used to provide contact between finely divided solids in the TF effluent and recycled biological solids and to provide additional soluble BOD removal if necessary. The contact opportunity provides for initial flocculation of dispersed solids into floc. The length of the aerobic solids contact period is governed by the requirements for particulate and soluble BOD removal. The third element in the TF/SC process is the flocculation period. Flocculation is initiated in the contact tank and continues in the clarifier, perferably in a mildly stirred environment of a center well. The flocculation step promotes clear effluent and growth of large, settleable floc that is removed during secondary clarification.

The following primary characteristics distinguish TF/SC from other processes:

1. The main function of the contact tank and clarifier flocculation features is to increase flocculation and solids capture and reduce particulate BOD.

2. The majority of soluble BOD removal occurs in the TF.
3. Return sludge solids are mixed with TF effluent rather than with primary effluent, as with some other processes.
4. The aerated solids contact tank is not designed to nitrify, although nitrification may occur in the TF.
5. The aerated solids contact time is 1 hr or less, based on total flow including recycle.
6. The solids retention time (SRT) of the aerated solids contact tank is less than approximately 2 days.

Performance of Existing Facilities

Design and performance data were reviewed for six facilities located in Chilton, Wisconsin; Corvallis, Oregon; Medford, Oregon; Norco, California; Oconto Falls, Wisconsin; and Tolleson, Arizona. Most of the information used in the process evaluation comes from the four facilities described in Table 1.

The Corvallis plant was the first TF/SC plant in operation. The Oconto Falls facility was originally a rock TF plant that was not meeting its discharge limits; modifications to the facility included addition of a solids contact chamber and a new flocculator clarifier for secondary clarification. Tolleson was originally a two-stage rock TF plant treating industrial and residential flows. The first-stage rock filter was replaced with a 20-ft-deep plastic media filter with intermediate clarification, and the remaining rock filter was followed by aerated SC and a flocculator clarifier. The Medford plant was originally an activated sludge (AS) plant that was converted to a coupled TF/AS plant. This plant presently operates in the TF/SC mode since its flows and loads are significantly below design levels.

Monthly performance data for the four facilities listed in Table 1 are presented in Table 2. Clearly, these plants produce a high-quality effluent in all cases.

Field Investigations

A total of 29 weeks of field investigations were undertaken at four facilities to augment the information available from historical operating records. Special study objectives were as follows:

1. To assess the influence of cosettling waste secondary solids with raw sewage solids on primary sedimentation tank performance.
2. To assess soluble BOD removal kinetics with TF depth.
3. To assess the effect of TF loading on TF/SC performance.
4. To assess the effect of media type on aerated solids contact tank performance.
5. To assess the effect of aerated solids contact tank operating parameters on TF/SC performance.
6. To assess soluble BOD removal in the aerated solids contact tank.
7. To assess the effect of aeration rate on TF/SC performance.
8. To assess the effect of secondary clarifier overflow rate on final effluent quality.
9. To assess the effect of coagulant addition for phosphorus removal on TF/SC performance.

Conclusions

The following conclusions are based on the special study results and a review of historical operating records:

1. Cosettling—Primary treatment suspended solids (SS) removal averaged 53

Table 1. Design Data for Operating TF/SC Facilities

Element	Tolleson	Oconto Falls	Corvallis	Medford*
Design flow, m^3/s (mgd)				
ADWF	0.36 (8.3)	0.017 (0.38)	0.43 (9.7)	0.79 (18)
PWWF	0.78 (17.7)	0.033 (0.75)	1.23 (28.0)	2.63 (60)
Design loading, 1,000 kg/d (1,000 lb/day)				
BOD	10.9 (24.0)	0.30 (0.67)	4.94 (10.9)	15.9 (35)
SS	9.80 (21.6)	0.36 (0.79)	5.22 (11.5)	12.7 (28)
Primary overflow rate, m^3/m^2 d (gal/day/ft^2)	39.5 (970)	15.1 (370)	39.9 (980)	41.8 (1,025)
Trickling filter				
Media type	Plastic/rock+	Rock	Rock	Plastic
BOD loading, $g/m^3 \cdot d$ (lb/day/1,000 ft^3)	881/146+ (55/9.1)	561 (35)	384 (24)	1,840 (115)
Return sludge aeration time,† min	–¶	–¶	9	–¶
Aerated solids contact time,# min	9	8	2	**
Flocculator center well				
Percent of clarifier area	13	16	12	5
Detention time,# min	25	38	25	5
Secondary clarifier				
Overflow rate,++ $m^3/m^2 \cdot d$ (gal/day/ft^2)	17.9 (440)	12.2 (300)	19.1 (470)	29.3 (720)††
Sidewater depth, m (ft)	4.9 (16)	4.6 (15)	5.5 (18)	4.6 (15)
Sludge removal system	Suction header	Suction tube	Suction tube	Suction header – 1 Suction tube – 3
Weir Location	Inboard	Inboard	Inboard	Inboard

*Originally designed as coupled TF/AS plant. Design data for TF/AS.
+First stage/second stage.
†Based on 33 percent return rate.
¶Not used at this plant.
#Based on total flow including recycle.
**Contact time at existing flow of 8.8 mgd plus 33 percent return is 39 min.
++Based on total clarifier area.
††Based on existing number of clarifiers.

Table 2. *Monthly Performance at Operating TF/SC Facilities*

	Tolleson*			Oconto Falls*			Corvallis*			Medford+		
Parameter	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*	*High*	*Low*	*Average*
Influent flow												
Average, m^3/s	*0.29*	*0.22*	*0.27*	*0.02*	*0.01*	*0.02*	*0.78*	*0.25*	*0.46*	*0.43*	*0.36*	*0.39*
(mgd)	*(6.7)*	*(5.0)*	*(6.1)*	*(0.46)*	*(0.28)*	*(0.36)*	*(17.9)*	*(5.6)*	*(10.5)*	*(9.9)*	*(8.2)*	*(8.9)*
Influent characteristics												
BOD, mg/L	*350*	*222*	*277*	*179*	*119*	*146*	*188*	*48*	*108*	*173*	*142*	*157*
SS, mg/L	*300*	*192*	*224*	*152*	*100*	*118*	*191*	*112*	*154*	*159*	*119*	*138*
Temperature, °C	–†	–†	–†	*19*	*8*	*13*	*22*	*13*	*17*	*22*	*16*	*19*
Primary effluent												
BOD, mg/L	*373*	*107*	*173*	–†	–†	–†	*114*	*35*	*70*	*90*	*76*	*81*
SS, mg/L	*400*	*57*	*121*	–†	–†	–†	*82*	*56*	*66*	*38*	*29*	*34*
TF effluent												
BOD, mg/L	*42.5¶*	*10.4¶*	*22.8¶*	–†	–†	–†	*39*	*22*	*30*	*81*	*51*	*66*
SS, mg/L	*45.9¶*	*9.9¶*	*23.6¶*	–†	–†	–†	*72*	*54*	*59*	*89*	*39*	*71*
Return sludge SS, g/L	–#	–#	–#	–#	–#	–#	*17.2*	*5.4*	*11.3*	–#	–#	–#
Mixed liquor SS, mg/L	*1,621*	*551*	*1,042*	–†	–†	–†	*4,982*	*1,557*	*3,127*	*1,868*	*1,475*	*1,615*
*Secondary effluent***												
BOD, mg/L	*15.4*	*3.5*	*7.2*	*31.7*	*14.2*	*20.9*	*9*	*5*	*6.8*	*23*	*14*	*19*
CBOD, mg/L	–†	–†	–†	–†	–†	–†	*7*	*4*	*5.1*	*11*	*6*	*8*
SS, mg/L	*20.2*	*4.0*	*8.5*	*22.6*	*6.1*	*12.8*	*13*	*7*	*9.4*	*9*	*6*	*8*

**April 1983 through March 1984.*
+April 1984 through July 1984.
†Not routinely measured.
¶Intermediate clarifier effluent.
#Return sludge aeration not used.
***Monthly averages.*

to 62 percent at three TF/SC plants that cosettle and 74 percent at Medford, which does not cosettle. The Meford results are exceptional. Primary sludge concentrations were 3.7 and 5.3 percent at the two plants practicing cosettling where samples could be obtained for analysis.

2. TF Soluble BOD Removal—The Velz equation successfully modeled soluble carbonaceous BOD_5 removal with TF depth at Tolleson.

3. TF Loading—In the range of average TF BOD_5 loadings studied under this project (5.8 to 29 lb/day per 1000 ft^3), BOD_5 loading does not always exert a strong influence on final effluent SS. Final effluent SS were always correlated with TF effluent SS, which are most sensitive to primary effluent SS concentration. The results show the need for reliable primary treatment and consideration of the effect of primary effluent SS on final effluent quality.

4. Solids Retention Time (SRT)—Correlations between SRT in the aerated solids contact tank and final effluent SS were not statistically significant at Corvallis and Tolleson. A statistically significant but weak correlation was observed at Medford.

5. Mixed Liquor Suspended Solids (MLSS)—MLSS concentrations of 900 to 2300 mg/L at Medford and Tolleson did not affect final effluent SS significantly and only produced an average increase of about 2 mg/L at Corvallis where the MLSS concentration varied from 1500 to 7000 mg/L. The insensitivity to mixed liquor level means simplification of operation, since less attention can be given to sludge inventory management.

6. Sludge Volume Index (SVI)—SVI values varied from 60 to 130 mL/g at Medford, and increasing values were correlated with reduced final effluent SS. No correlation was observed at Tolleson or Corvallis. Corvallis and Tolleson have large flocculator center wells, whereas those at Medford are much smaller.

7. Solids Flocculation—Field test results at Medford suggest the majority of flocculation in the aerated solids contact channel occurs within the first 12 min of aerated solids contact time in a channel that has a total hydraulic retention time of 39 min. Additional SS removal occurs in the flocculator center well. The results agree with observations at Corvallis, Oregon.

8. Contact Tank Soluble BOD Removal—Although the primary function of the contact tank is to flocculate SS and particulate BOD, a significant fraction of the filter effluent soluble BOD can be removed. The Medford contact tank removed an average of 75 percent of the residual soluble BOD from the filter in 39 min of contact time.

9. Secondary Clarifier Overflow Rate—Secondary clarifiers that include inboard launders, high sidewater depths, and flocculator center wells are insensitive to 1300 gpd/ft^2 at Corvallis and up to 700 gpd/ft^2 at Tolleson. These are the maximum overflow rates at these respective plants.

10. Coagulant Addition—Ferric chloride addition in the aerated solids contact tank for phosphorus removal at Oconto Falls did not adversely affect TF/SC operation.

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Raymond N. Matasci, Arthur H. Benedict, and Denny S. Parker are with Brown and Caldwell Consulting Engineers, Pleasant Hill, CA 94523.
***James F. Kreissl** is the EPA Project Officer (see below).*
The complete report, entitled "Trickling Filter/Solids Contact Process: Full-Scale Studies," (Order No. PB 86-183 100/AS; Cost: $16.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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