EXHIBIT C

CHAIN-OF-CUSTODY

CITY OF SAN DIEGO
METROPOLITAN WASTEWATER DEPARTMENT
ENVIRONMENTAL MONITORING & TECHNICAL SERVICES DIVISION
WASTEWATER CHEMISTRY LABORATORY
5530 Kiowa Drive
La Mesa, CA 91942
(619) 668-3215

SAMPLING REPORT & CHAIN OF CUSTODY RECORD – DAILY SAMPLING (BOD/SBOD)

Project/Client:	Brown and Caldwell / EPMD	Sampler/s:		Type of Sampling Equipment/How sample obtained/other sampling notes:
Contact Name:	Victor Occiano	Contact Name:	Joe Cordova	ISCO Autosampler – Time Composited
Phone/Fax:	(619) 203-3077 / (858) 514-8833	Phone:	619-221-8728	

Sample Information: (All information is required) Number of attachments: _________

Date/Time Sample Taken	Sampler	Source / Location	Sample Type/Description	Grab / Composite	Total vol/wt mLs / Gms	Number of containers	Container Type	Preservative	Analyses requested	Sample Log Number (Lab use only)
		Influent/ 13-Inf	Daily	Composite			P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	
		Biostyr Effluent / 13-BSEff	Daily	Composite		1	P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	
		Biofor-C Effluent / 13-BFCEff	Daily	Composite	1	1	P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	
		Biofor-N Effluent / 13-BFNEff	Daily	Composite		1	P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	

Chain-of-Custody

Relinquished by:	Received by:	Date & Time	Comments
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	Reviewed by: Date:

See instructions, on reverse, for completing this form.

FIGURE 2a

Location:

Original - retained by Lab.1st copy - Transporter
Last copy - for sample originator

CITY OF SAN DIEGO
METROPOLITAN WASTEWATER DEPARTMENT
ENVIRONMENTAL MONITORING & TECHNICAL SERVICES DIVISION
WASTEWATER CHEMISTRY LABORATORY
5530 Kiowa Drive
La Mesa, CA 91942
(619) 668-3215

SAMPLING REPORT & CHAIN OF CUSTODY RECORD – DAILY SAMPLING (CBOD/SCBOD)

Project/Client:	Brown and Caldwell / EPMD	Sampler/s:		Type of Sampling Equipment/How sample obtained/other sampling notes:
Contact Name:	Victor Occiano	Contact Name:	Joe Cordova	ISCO Autosampler – Time Composited
Phone/Fax:	(619) 203-3077 / (858) 514-8833	Phone:	619-221-8728	

Sample Information: (All information is required) Number of attachments: _________

Date/Time Sample Taken	Sampler	Source / Location	Sample Type/Description	Grab / Composite	Total vol/wt mLs / Gms	Number of containers	Container Type	Preservative	Analyses requested	Sample Log Number (Lab use only)
		Influent/ 13-Inf	Daily	Composite			P	4 °C	$CBOD_5$, $SCBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	
		Biostyr Effluent / 13-BSEff	Daily	Composite		1	P	4 °C	$CBOD_5$, $SCBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	
		Biofor-C Effluent / 13-BFCEff	Daily	Composite	1	1	P	4 °C	$CBOD_5$, $SCBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	
		Biofor-N Effluent / 13-BFNEff	Daily	Composite		1	P	4 °C	$CBOD_5$, $SCBOD_5$, COD, TSS, VSS, TKN, NH_3-N, Ort-P, Alkalinity	

Chain-of-Custody

Relinquished by:	Received by:	Date & Time
Name: Sign:	Name: Sign:	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:

Comments

Reviewed by: Date:

See instructions, on reverse, for completing this form.

FIGURE 2a

Location:

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CITY OF SAN DIEGO
METROPOLITAN WASTEWATER DEPARTMENT
ENVIRONMENTAL MONITORING & TECHNICAL SERVICES DIVISION
WASTEWATER CHEMISTRY LABORATORY
5530 Kiowa Drive
La Mesa, CA 91942
(619) 668-3215

SAMPLING REPORT & CHAIN OF CUSTODY RECORD – EVERY OTHER DAY (BACKWASH SAMPLES)

Project/Client: Brown and Caldwell / EPMD	Sampler/s:	Type of Sampling Equipment/How sample obtained/other sampling notes:
Contact Name: Victor Occiano	Contact Name: Joe Cordova	Grab Sample from Backwash Tank/Recycle Pump
Phone/Fax: (619) 203-3077 / (858) 514-8833	Phone: 619-221-8728	

Sample Information: (All information is required) Number of attachments: _________

Date/Time Sample Taken	Sampler	Source / Location	Sample Type/Description Grab / Composite	Total vol/wt mLs / Gms	Number of containers	Container Type	Preservative	Analyses requested	Sample Log Number (Lab use only)
		Biostyr Backwash/ 13-BSBW	Every Other Day		1	P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TS, VS, SETS	
		Biofor-C Backwash / 13-BFCBW	Every Other Day		1	P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TS, VS, SETS	
		Biofor-N Backwash / 13-BFNBW	Every Other Day Grab		1	P	4 °C	BOD_5, $SBOD_5$, COD, TSS, VSS, TS, VS, SETS	
			Grab						

Grab

Chain-of-Custody

Relinquished by:	Received by:	Date & Time
Name: Sign:	Name: Sign:	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:

Comments

Reviewed by:	Date:

See instructions, on reverse, for completing this form.

FIGURE 2a

Location:

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CITY OF SAN DIEGO
METROPOLITAN WASTEWATER DEPARTMENT
ENVIRONMENTAL MONITORING & TECHNICAL SERVICES DIVISION
WASTEWATER CHEMISTRY LABORATORY
5530 Kiowa Drive
La Mesa, CA 91942
(619) 668-3215

SAMPLING REPORT & CHAIN OF CUSTODY RECORD – OCCASIONAL SAMPLING

Project/Client: Brown and Caldwell / EPMD	Sampler/s:	Type of Sampling Equipment/How sample obtained/other sampling notes:
Contact Name: Victor Occiano	Contact Name: Joe Cordova	ISCO Autosampler
Phone/Fax: (619) 203-3077 / (858) 514-8833	Phone: 619-221-8728	

Sample Information: (All information is required) Number of attachments: _________

Date/Time Sample Taken	Sampler	Source / Location	Sample Type/Description	Grab / Composite	Total vol/wt mLs / Gms	Number of containers	Container Type	Preservative	Analyses requested	Sample Log Number (Lab use only)
		Influent/ 13-Inf	Two times per week Two times for whole study Once for whole study	Composite Composite-Diurnal Composite-Diurnal		 1 1	P P P	4 °C 4 °C 4 °C	(NO_3-N +NO_2-N), NO_2-N $CBOD_5$ $SCBOD_5$	
		Biostyr Effluent / 13-BSEff	Two times per week Two times for whole study Once for whole study	Composite Composite-Diurnal Composite-Diurnal		 1 1	P P P	4 °C 4 °C 4 °C	(NO_3-N +NO_2-N), NO_2-N $CBOD_5$ $SCBOD_5$	
		Biofor-C Effluent / 13-BFCEff	Two times per week Two times for whole study Once for whole study	Composite Composite-Diurnal Composite-Diurnal	 1	 1 1	P P P	4 °C 4 °C 4 °C	(NO_3-N +NO_2-N), NO_2-N $CBOD_5$ $SCBOD_5$	
		Biofor-N Effluent / 13-BFNEff	Two times per week Two times for whole study Once for whole study	Composite Composite-Diurnal Composite-Diurnal	 1	 1 1	P P P	4 °C 4 °C 4 °C	(NO_3-N +NO_2-N), NO_2-N $CBOD_5$ $SCBOD_5$	

1

Chain-of-Custody

Relinquished by:	Received by:	Date & Time	Comments
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time 1	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	Reviewed by: / Date:

See instructions, on reverse, for completing this form.

FIGURE 2a

Location:

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CITY OF SAN DIEGO
METROPOLITAN WASTEWATER DEPARTMENT
ENVIRONMENTAL MONITORING & TECHNICAL SERVICES DIVISION
WASTEWATER CHEMISTRY LABORATORY
5530 Kiowa Drive
La Mesa, CA 91942
(619) 668-3215

SAMPLING REPORT & CHAIN OF CUSTODY RECORD – TKN SAMPLE ANALYSIS

Project/Client:	Brown and Caldwell / EPMD	Sampler/s:		Type of Sampling Equipment/How sample obtained/other sampling notes:
Contact Name:	Victor Occiano	Contact Name:	Brent Bowman	TKN Samples for BAF Pilot Study
Phone/Fax:	(619) 203-3077 / (858) 514-8833	Phone:	619-221-8765	

Sample Information: (All information is required) Number of attachments: _________

Date/Time Sample Taken	Sampler	Source / Location	Sample Type/Description	Grab / Composite	Total vol/wt mLs / Gms	Number of containers	Container Type	Preservative	Analyses requested	Sample Log Number (Lab use only)
		Influent/ 13-Inf	Daily	Composite		1	P	4 °C	TKN	
		Biostyr Effluent / 13-BSEff	Daily	Composite		1	P	4 °C	TKN	
		Biofor-C Effluent / 13-BFCEff	Daily	Composite		1	P	4 °C	TKN	
		Biofor-N Effluent / 13-BFNEff	Daily	Composite		1	P	4 °C	TKN	
		Influent/ 13-Inf	Daily	Composite		1	P	4 °C	TKN	
		Biostyr Effluent / 13-BSEff	Daily	Composite		1	P	4 °C	TKN	
		Biofor-C Effluent / 13-BFCEff	Daily	Composite		1	P	4 °C	TKN	
		Biofor-N Effluent / 13-BFNEff	Daily	Composite		1	P	4 °C	TKN	

Chain-of-Custody **Comments**

Relinquished by:	Received by:	Date & Time	Comments
Name: Sign:	Name: Sign:		
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	Reviewed by: Date:

See instructions, on reverse, for completing this form.

FIGURE 2a

Location:

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Last copy - for sample originato

CITY OF SAN DIEGO
METROPOLITAN WASTEWATER DEPARTMENT
ENVIRONMENTAL MONITORING & TECHNICAL SERVICES DIVISION
WASTEWATER CHEMISTRY LABORATORY
5530 Kiowa Drive
La Mesa, CA 91942
(619) 668-3215

SAMPLING REPORT & CHAIN OF CUSTODY RECORD – BACTERIA SAMPLE ANALYSIS

Project/Client:	Brown and Caldwell / MWWD	Sampler/s:	Smoczynski/ Suhendra	Type of Sampling Equipment/How sample obtained/other sampling notes:	
Contact Name:	Victor Occiano	Contact Name:	Brent Bowman	MS2 Phage, Enterococcus, Total and Fecal Coliform for BAF Pilot Study	
Phone/Fax:	(619) 203-3077 / (858) 514-8833	Phone:	619-221-8765		

Sample Information: (All information is required) Number of attachments: _________

Date/Time Sample Taken	Sampler	Source / Location	Sample Type/Description Grab / Composite	Total vol/wt mLs / Gms	Number of containers	Container Type	Preservative	Analyses requested	Sample Log Number (Lab use only)
	Smoczynski/ Suhendra	13-INF	Grab Sample	250	1	P	Blue Ice	MS2 phage, enterococcus, Total and Fecal Coliform	
	Smoczynski/ Suhendra	13-BFCEFF	Grab Sample	250	1	P	Blue Ice	MS2 phage, enterococcus, Total and Fecal Coliform	
	Smoczynski/ Suhendra	13-BFNEFF	Grab Sample	250	1	P	Blue Ice	MS2 phage, enterococcus, Total and Fecal Coliform	
	Smoczynski/ Suhendra	13-BSEFF	Grab Sample	250	1	P	Blue Ice	MS2 phage, enterococcus, Total and Fecal Coliform	

Chain-of-Custody **Comments**

Relinquished by:	Received by:	Date & Time	Comments
Name: Sign:	Name: Sign:		
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	
Relinquished by: Name: Sign:	Received by: Name: Sign:	Date & Time Location:	Reviewed by: Date:

See instructions, on reverse, for completing this form.

FIGURE 2a

Location:

Original - retained by Lab.1st copy - Transporter
Last copy - for sample originato

Instructions for completing the
SAMPLING REPORT & CHAIN-OF-CUSTODY RECORD
FIGURE 2b

Prior to the acceptance into the Wastewater Chemistry Laboratory of **any sample**, this form will be completed by the sampler and submitting agency.

This form will be completed by the sampler at the time of sampling. Each person who takes custody of the sample must sign for acceptance (Received by:), and then again, upon relinquishing the sample to another person. The laboratory will sign for the acceptance and then provide a copy of this form to the person submitting the sample. The laboratory will maintain the originals of completed SAMPLING REPORT & CHAIN-OF-CUSTODY RECORDs in the laboratory.

The Sample information will be completed by the sampler/submitting agency in full. The following information is the minimum required and a column for this data is provided for on the form.

! Who is requesting the sample/analysis or what project the sample is for; include name and phone number.

! Who performed the sampling; include name and phone number.

! Any pertinent supporting information about the sampling, the sample, the location, weather, etc.

! How the samples was obtained, what sampling equipment used, and other information about the sampling event.

! Date and time of sampling.

! Source and location where the sample was taken, please provide full descriptive information.

Examples: Fiesta Is. Drying Bed #2; Fiesta Is. Dried Sludge Pile #16; PLR COMP, PLE COMP, Pt. Loma headworks;

! Sample type/description.

Examples: Decant/return stream; Dried Sludge; PLR-sewage influent Pt Loma;

! Total amount of sample, in mLs or Grams or other convenient measure.

! Number of sample containers. Should be the total for each sampling event/log number.

! Container Type; eg. 1L glass bottle, 5 gal plastic, etc.

! Preservative used; eg., HCl to pH <4, refeer, frozen, etc.

! Analysis/es requested; eg. BOD, Total Solids, % Moisture, Pesticides, Cyanides, etc.

! The SAMPLE LOG number is reserved for laboratory personnel who log the sample into the laboratory.

CHAIN-OF-CUSTODY

Sample chain-of-custody can be an important method to ensure that samples are properly identified, preserved, analyzed and reported. Also, the ability to document the possession of a sample throughout its analytical life may become a legal issue. Each person who takes possession and control of the sample will document the change of custody in the Chain-of-Custody part of the SAMPLING REPORT & CHAIN-OF-CUSTODY RECORD form. If you give the sample to someone (for example, to transport it to the lab.) you must complete the first available "Relinquished by" section and have the person you are giving the sample to complete the "Received by" section adjacent. Enter the date & time of the transaction in the Date & time block. Record where the transfer of custody took place in this block. The laboratory should provide the submitter with a copy of this form, retaining the original in lab. records.

COMMENTS

In addition to the previous Remarks section, this section is for comments concerning the sample, condition of sample upon transfer or receipt, delays in transfer, special instructions or other information relevant to the sample or sampling event. You are encouraged to make any comment that may have a bearing on the sample, its handling or its analysis.

EXHIBIT D

COMPOSITE SAMPLING INSTRUCTIONS

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study – Phase 1

Composite Sampling Instructions

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1. Obtain daily log sheets from the Operations Supervisors Office (1st floor of the Operations Bldg & Visitors Center (OBVC)). The pertinent sheets should be part of the package of sheets on a clip board.

2. Ensure that the proper log sheets and chain-of-custody forms have been included by cross checking it with the schedule (should be posted nearby)

3. Obtain pre-labeled composite bottles from the PLWTP Lab and proceed to the pilot test pad.

4. Replace the filled pre-labeled bottles contained in each autosampler with the respective pre-labeled empty bottles obtained under Step 1.

5. Fill out the Chain-of-Custody (COC), including time and date when samples were collected and the total volume of samples in each container (the plastic bottles should have graduations which can be used for estimation).

6. DO NOT re-program the autosampler

7. Bring filled, pre-labeled composite bottles to the PLWTP Lab

8. Provide the PLWTP Lab staff the completed COC. The lab staff will sign the COC to and fax a copy of the completed form to Victor Occiano or BC (Fax No. 858-514-8833)

9. Proceed with portable meter and instrumentation readings (on a separate instruction sheet)

EXHIBIT E

DAILY PILOT TEST METER AND INSTRUMENTATION READINGS LOG SHEETS

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Daily Pilot Test Unit Instrument & Meter Readings
@ NORMAL OPERATIONS

Location: BIOFOR C Date: ______ **Time:** ______ **Analyst:** ______

INSTRUMENT READINGS – BIOFOR C		PORTABLE METER READINGS – 13BFCEff	
Parameter	**Value**	**Parameter**	**Value**
Process Air Flow, scfm		pH	
Influent flow, gpm		Temperature, °C	
Influent Valve Closure, %		DO, mg/L	
Column Pressure, psi		Turbidity, NTU	
Water Level in BIOFOR C Effluent Storage Tank Rising?	YES ☐ NO ☐ If no, adjust BIOFOR N Box Screen Valve	Effluent characteristics (visual, odor)	
BIOFOR N Box Screen Valve Adjustment; # Turns			
Media loss	YES ☐ NO ☐	If Yes, what is the amount (1-4) where 1= 0-Few; 4= Severe Amount =	
Condition of Screen (solids buildup, overflow, collected solids)			
Other observations			

Location: BIOFOR N Date: ______ **Time:** ______ **Analyst:** ______

INSTRUMENT READINGS – BIOFOR N		PORTABLE METER READINGS – 13BFNEff	
Parameter	**Value**	**Parameter**	**Value**
Process Air Flow, scfm		pH	
Influent flow, gpm		Temperature, °C	
Influent Valve Closure, %		DO, mg/L	
Column Pressure, psi		Turbidity, NTU	
		Effluent characteristics (visual, odor)	
Media loss	YES ☐ NO ☐	If Yes, what is the amount (1-4) where 1= 0-Few; 4= Severe Amount =	
Other observations			

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Daily Pilot Test Unit Instrument & Meter Readings
@ NORMAL OPERATIONS

Location: 13INF **Date**: ______ **Time:** ______ **Analyst:** ______

PORTABLE METER READINGS - 13Inf		**OBSERVATIONS**	
Parameter	**Value**		**Value/Comment**
Temperature, °C		BAF Influent Tank Overflowing?	Yes ☐ No ☐ If no, check influent pump
DO, mg/L		Influent Pump Operating?	Yes ☐ No ☐ If no, call Victor Occiano @ (619) 203-3077 or Amer Barhoumi @ (619) 922-6421 and wait for instructions
pH reading of 7.0 Buffer		Influent Pump Primed? Water Flowing?	Yes ☐ No ☐ If no, call people listed above
Calibrated pH slope (BC and EPMD only)			
pH			
Turbidity, NTU		Provide Reason for pump failure	
UVT, %		Check DO Probe Membrane for Air Bubbles	Yes ☐ No ☐ If yes, notify Mitch Dornfeld, EPMD staff or BC staff to replace membrane
Other Observations			

Location: **BIOSTYR** **Date**: ______ **Time:** ______ **Analyst:** ______

INSTRUMENT READINGS - BIOSTYR		**PORTABLE METER READINGS – 13BSEff**	
Parameter	**Value**	**Parameter**	**Value**
Process Air Flow, scfm		pH	
Influent flow, gpm		Temperature, °C	
Backwash flow, gpm		DO, mg/L	
Effluent DO, mg/L		Turbidity, NTU	
Inlet Pressure, iwc		UVT, %	
Effluent pH, pH Unit			
Headloss, iwc		Effluent characteristics (visual, odor)	
Time till next BW, hr.			
Max time between BW, hr.			

Media loss	YES ☐ NO ☐ - If Yes, what is the amount (1-4) where 1= 0-Few; 4= Severe Amount =
Other observations	

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bi-Daily Pilot Test Unit Instrument Readings
DURING BACKWASH SAMPLING EVENT

Location: BioFor C **Date**: ____ **Time:** ____ **Analyst:** ____

INSTRUMENT READINGS – BIOFOR C BACKWASH EVENT	
Parameter	**Set Point/Operating Point**
Process Air Flow, scfm	
Influent flow, gpm	
Backwash Air Flow, scfm	
Backwash flow, gpm	
Inlet Pressure, iwc	
Headloss, iwc	
Time till next BW, min	
Max time between BW, min	
Media loss	- YES ☐ NO ☐ If Yes, what is the amount (1-4) where 1= 0-Few; 4= Severe Amount =
Other observations	

Location: BioFor N **Date**: ____ **Time:** ____ **Analyst:** ____

INSTRUMENT READINGS – BIOFOR N BACKWASH EVENT	
Parameter	**Set Point/Operating Point**
Process Air Flow, scfm	
Influent flow, gpm	
Backwash Air Flow, scfm	
Backwash flow, gpm	
Inlet Pressure, iwc	
Headloss, iwc	
Time till next BW, min	
Max time between BW, min	
Media loss	- YES ☐ NO ☐ If Yes, what is the amount (1-4) where 1= 0-Few; 4= Severe Amount =
Other observations	

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bi-Daily Pilot Test Unit Instrument Readings
DURING BACKWASH SAMPLING EVENT

Location: BioStyr **Date**: ______ **Time:** ______ **Analyst:** ______

INSTRUMENT READINGS - BIOSTYR	
Parameter	**Set Point/Operating Point**
Process Air Flow, scfm	
Influent flow, gpm	
Backwash Air Flow, scfm	
Backwash flow, gpm	
Effluent DO, mg/L	
Inlet Pressure, iwc	
Effluent pH, pH Unit	
Headloss, iwc	
Time till next BW, min	
Max time between BW, min	
Media loss	- YES ☐ NO ☐ If Yes, what is the amount (1-4) where 1= 0-Few; 4= Severe Amount =
Other observations	

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Imhoff Cone Testing

Location: BioFor N **Date**: ____ **Time:** ____ **Analyst:** ____

Minutes:	**mL**
15	
30	
Observations:	

Location: BioFor C **Date**: ____ **Time:** ____ **Analyst:** ____

Minutes:	**mL**
15	
30	
Observations:	

Location: BioStyr **Date**: ____ **Time:** ____ **Analyst:** ____

Minutes:	**mL**
15	
30	
Observations:	

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study – Phase 1

DO Meter Instructions

Note: Dissolved oxygen measurements will be taken daily from the 13-Influent, BioFor C effluent, BioFor N effluent and BioStyr Effluent sampling ports and recorded on the daily field log sheets. **Prior to taking DO readings with portable meter, confirm that no air bubbles have accumulated under the probes membrane.** If air bubbles are present under the membrane contact either Mitch Dornfeld, EPMD staff or Brown and Caldwell staff to replace membrane prior to taking DO measurement.

To measure DO content using the portable DO meter follow the steps listed below.

1. Attach the DO probe to the portable DO meter.
2. Confirm that the probe guard is attached to the end of the probe and that the probe guard contains a small amount of paper towel, which is saturated with DI water. If paper towel has dried out, add DI water until towel is saturated.
3. Set the function switch to the ZERO mode and zero the instrument using the top left (zero) knob.
4. Set the function switch to Temp 5-45 degrees C and note the temperature.
5. Look on the back of the DO meter and note the saturated DO level that corresponds to the temperature read in step 5.
6. With saturated probe guard attached to the probe, set the function switch to the DO measuring setting (DO mg/L) and adjust the DO value using the top right knob until it matches the saturated DO value measured from the table on the back of the instrument during step 5.
7. You are now ready to measure DO content of the sample. Insert probe into sample and when stabilized record value on daily log sheet.

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study – Phase 1

pH/Temp Meter Instructions

Note: Temperature and pH measurements should be taken daily from the 13-Influent, BioFor C effluent, BioFor N effluent and BioStyr effluent sampling ports and recorded on the field log sheets. Brown and Caldwell staff will calibrate the pH meter on weekends and EPMD staff will perform the weekday calibrations. The calibration and testing procedures are as noted below:

Autocalibration with Two and Three Buffers / pH Measurement Instructions

1. Connect the electrode(s) to meter.

   For 2-point Cal: Choose either 4.01 and 7.00 or 7.00 and 10.01 buffers, whichever bracket your expected sample range.

   For 3-point Cal: Choose 4.01, 7.00 and 10.01 buffers

2. Press the **mode** key until the pH mode indicator is displayed.

3. Rinse the electrode(s) and place into the first buffer.

4. Press the **2nd** then the **cal** keys. CALIBRATION is displayed above the main field and the time and date of the last calibration are displayed. After a few seconds, P1 is displayed in lower field. P1 indicates that the meter is ready for the first buffer and a value has not yet been entered. When READY is displayed, indicating electrode stability, the reading begins to flash, press the **yes** key. The display will remain frozen for two seconds. Then P2 will be displayed in the lower field indicating that the meter is ready for the second buffer.

   For 2-point Cal: Rinse the electrode(s) and place into the second buffer. When READY is dislayed, press the **yes** key. Press the **measure** key to end calibration at two points. SLP appears in the lower field with the actual electrode slope, in percent, in the field.

   For 3-point Cal: Rinse the electrode(s) and place into the third buffer. When READY is dislayed, press the **yes** key. After the third buffer value has been entered, the electrode slope will be displayed. SLP appears in the lower field with the actual electrode slope, in percent, in the main field.

   The meter automatically advances to the measure mode. MEASURE is displayed above the main field.

5. Rinse the electrode(s) and place into sample. Record pH directly from the meter display and temperature from the lower field.

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study – Phase 1

Turbidity Meter Instructions

Note: Turbidity measurements should be taken daily from the 13-Influent, BioFor C effluent, BioFor N effluent and BioStyr effluent sampling ports and recorded on the daily field log sheets. The procedure to measure turbidity is as noted below:

1. Inspect measurement cell and ensure it is free of dirt or foreign particles. Obtain a representative sample in a clean container and fill sample cell with approximately 15 mL, up to the marked line. Handle measurement cell by holding it at the top.
2. Wipe the measurement cell clean on the outside using a clean, soft lint free cloth. Ensure there are no fingerprints, smudges or waterspots to interfere with the measurement.
3. Apply a thin film of silicone oil to the outside of the cell. Wipe with a soft cloth to obtain an even film over the entire surface.
4. Turn the instrument on and place it on a flat sturdy surface.
5. Insert sample cell in the instrument cell compartment so that the diamond orientation mark aligns with the raised orientation mark in front of the cell compartment. **Close the lid.**
6. Press **READ** to obtain reading. Display will indicate **- - - - - NTU** and then the turbidity in NTU. Record the turbidity after the lamp symbol turns off.

EXHIBIT F

PRESSURE TRANSDUCER DATA DOWNLOAD INSTRUCTIONS

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study – Phase 1

Instructions to Download BAF Pilot Column Pressure Data and Turbidity Data

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Note: Column pressure data should be downloaded from each of the three units on Mondays, Wednesdays and Fridays immediately following completion of the BioFor C backwash cycle and e-mailed to Victor Occiano for review (Brown and Caldwell, vocciano@brwncald.com).

Download Instructions:

Download recorded data from pressure datalogger to field computer

1. Connect the 9-pin “D” serial port on the laptop computer to the CR10 datalogger located inside the white fiberglass enclosure at the pilot test unit using the serial cable with optical isolator (kept inside the enclosure).
2. Turn on and log into the laptop computer using the username: vendor and password: vendor.
3. Run the LoggerNet program.
4. Double click on the connect icon on LoggerNet main menu bar. (If the “Connect Screen” is already open, skip this step)
5. Click on the “Connect” button on the “Connect Screen”.
6. After connection established, click the “Collect Now” button.

Split 5-minute records from raw data file and generate new data file with windows compatible time stamp for each record

7. Double click “Split” icon on LoggerNet main menu bar.
8. On the “Split” screen, Select “File”, then double click the file “Baf_5min.par” on the recently used list of files.
9. On the “Split” screen, click the “Run” button, then click “Go”.
10. This step generates a “Baf_5min.csv” file without column headers. CSV stands for comma separated values, a text file recognized by excel directly.

Add Column Headers to csv file

11. Double click Total Commander icon on the Desktop.
12. Double click on the BAT file (batch) “addheadr-5min.bat”.
13. This creates the excel compatible file Baf_5min_h.csv”

View the csv file in Excel

14. Double click “BAF_5min_h.csv”. This will open the file in excel.
15. No need to save unless modifying or re-naming.

EXHIBIT G

BACKWASH SAMPLING INSTRUCTIONS

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study – Phase II

BioFor N, BioStyr and BioFor C Backwash Sampling Instructions

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Note: Backwash sampling will be performed every other day and will consist of the following activities to be performed in the order listed:

1. Operation of BioFor N unit during backwash cycle. Documenting filtration and backwash operating set points. Collection of BioFor N backwash sample. Adjusting BioFor N unit as needed to maintain operating set points.

2. Monitoring of BioStyr unit during backwash cycle. Collection of BioStyre backwash sample. Adjusting BioStyre unit as needed to maintain operating set points.

3. Operation of BioFor C unit during backwash cycle. Documenting filtration and backwash operating set points. Collection of BioFor C backwash sample. Adjusting BioFor C unit as needed to maintain operating set points.

4. Downloading column pressure and turbidity data from the BioFor and BioStyr units and e-mailing the data to Victor Occiano (Brown and Caldwell, vocciano@brwncald.com).

BioFor N

1. After collecting three (3) prelabeled backwash sample bottles and chain-of-custody forms from the PLWTP lab, arrive at BioFor N unit at 09:40. **Confirm the amount of time until the next backwash cycle begins** (backwash should be set to automatically begin at 10:00). To do this, go to the **main menu** of the BioFor N control screen and select **Misc. Timers**. This will bring up a screen that shows the set time between backwash events and the time that has expired since the last backwash event**.** Confirm that the backwash is scheduled to begin at 10:00 by subtracting the time that has expired since the last backwash event from the set time between backwash events and adding the result to the current time (i.e. 1391-1371 = 20 min, 20 min + 09:40 = 10:00 / check).

2. **Record values of influent wastewater flow, process airflow and column pressure on daily log sheet while the system is in filter mode** (i.e. before backwash begins at 10:00). Make note of values that differ from set points indicated on the instrument and report significant differences (>10%) to Victor Occiano (Brown and Caldwell, 619-203-3077). Note: Set points can be checked by going to the **main menu** of the BioFor N control screen, **selecting PID Control, diff pressure** and by reading appropriate values from either the backwash flow loop, process air flow loop, influent flow loop or air scour flow loop screens.

3. **Open BioFor backwash tank inlet valve** located on backside of main backwash holding tank to allow backwash flow from BioFor N unit to enter the tank.

4. **Close backwash tank drain.**

5. The BioFor N backwash cycle will begin automatically at 10:00. During the 47-minute cycle, the system will go through several processes (i.e. air scour, backwash flow). **To monitor backwash progress**, go to the **main menu** of the BioFor N control screen and select **Change Step Times**. This will take you to a screen listing each backwash process, duration, and status.

Note:

Just prior to the scheduled backwash initiation time, position yourself to perform step 6 <u>approximately 2 minutes before</u> the BioFor N system switches itself into backwash mode.

6. At approximately 09:58 (2 minutes before the BioFor N backwash cycle begins) you will need to **adjust the backwash drain valves to redirect the backwash flow to the backwash storage tank for sampling**. To do this orient both of the backwash drain valves in the horizontal position (such that the valve on the vertical pipe is closed and the valve on the horizontal pipe is open). Note: See yellow instruction labels for assistance.

7. Monitor the system during the 47-minute backwash cycle and **record the backwash wastewater flow rate and backwash process airflow rate** on the daily log sheet. **Note**: The first process of a backwash cycle is an air scour. During the 3-minute air scour, you must observe the air scour rate show on the yellow meter. During this phase the air scour rate will tend to fluctuate as he pressure in the column changes. You must adjust the air scour blow off as needed to maintain the set point listed in yellow on the air scour meter. **Make note of values that differ from the set points** in the general observation section of the log sheet. Note: Set points can be checked by going to the **main menu** of the BioFor N control screen, **selecting PID Control, diff pressure** and by reading appropriate values from either the backwash flow loop, process air flow loop, influent flow loop or air scour flow loop screens.

   Adjust the valve on backwash drain line as needed to obtain the set backwash flow rate. Adjust the valve on the backwash air scour blow off as needed to obtain the set backwash air scour flow rate. **Note all valve adjustments made** on the daily log sheet.

8. During backwash you should **notice the backwash tank level rise** as fluid is added. **If the backwash tank level is not rising** then there is a problem with the backwash valve configuration and **steps 3, 4 and 6 must be checked <u>immediately</u>**.

9. If operating correctly the backwash tank level will rise during backwash as fluid is added. When the backwash tank water level raises approximately 1foot from the bottom of the tank, the **backwash recirculation pump must be turned on**. The backwash recirculation pump is located behind the intermediate pump station for the

BioStyr unit (to the left of the backwash storage tank as you face East). To turn on backwash recirculation pump, plug in the recirculation pump's cord to the electrical outlet located behind the Biostyr Unit. The pump will need to remain on until you are finished taking the backwash sample.

10. At 10:46 the backwash cycle should be near completion. Confirm that the cycle is near completion by going to the **main menu** of the BioFor N control screen and selecting **Misc. Timer**.

Note:

Just prior to the completion of the backwash cycle, position yourself to perform step 11 <u>the instant</u> the BioFor N system switches into filtration mode. From this point you will have exactly 50 minutes to take the sample, drain the tank, clean the tank, rearrange the BioFor N backwash valves and to prepare for the BioStyr backwash sampling.

11. Immediately after the BioFor N backwash is complete and you have confirmed this, **you must adjust the backwash flow valves to allow for normal draining** by opening the valve on the vertical pipe and closing the valve on the horizontal pipe.

12. Immediately after performing step 11 you must **close the BioFor backwash tank inlet valve** located on backside of main backwash holding tank (the valve that was opened in step 3).

13. You are now ready to take your first sample. To take the sample, confirm that the backwash recirculation pump is running and collect the BioFor N backwash sample from the backwash sampling port located on the backwash recirculation line.

14. Once the sample is collected, **turn off the backwash recirculation pump** by unplugging it.

15. **Drain the backwash holding tank** by opening the valve on the backwash tanks main drain line and allow the liquid to drain to the sump located in front of the tank.

16. You are now ready to clean the backwash holding tank. Begin by closing the valve on the backwash tanks main drain line (the valve opened in step 14). Next, confirm that a hose is connected to the backwash tanks cleaning system and run the cleaning system for 5 minutes. After 5 minutes of wash down, drain the tank by plugging in the tank's sump pump. Once drained as far as the sump pump is capable, unplug the sump pump and repeat the wash down process two more times (a total of 3 times). Visually confirm that the tank is clean. If required, repeat the wash down process as necessary.

17. Finally, confirm that steps 11 and 12 have been performed correctly and that the **backwash tank drain is closed.** You are now ready to begin the next process

BioStyr

1. Move to the BioStyr control panel and **record values of influent wastewater flow, process airflow and column pressure on daily log sheet while the system is in filter mode** (i.e. before backwash begins at 11:45). Make note of values that differ from set points shown on the screen and report significant differences to Victor Occiano (Brown and Caldwell, 619-203-3077). Operating points can be read from the BioStyr's main control panel directly while set points can be observed by selecting the controls prompt from the main control screen.

2. The BioStyr Backwash cycle will begin automatically at 11:45. Note: During the backwash process, backwash water will be pumped through an intermediate pump station. If for any reason during the backwash cycle there is a problem with the pump station, an alarm will sound and you must shut down the system by switching it into manual off mode. At this point PLWTP staff should be notified to resolve any problems that may have occurred.

3. Monitor the system during the 18-minute backwash cycle and **record the backwash wastewater flow rate and backwash process airflow rate** on the daily log sheet. **Make note of values that differ from the set points** in the general observation section of the log sheet.

4. When the backwash tank water level raises approximately 1foot from the bottom of the tank, the **backwash recirculation pump must be turned on**. To turn on backwash recirculation pump, plug in the recirculation pump's cord to the electrical outlet located behind the Biostyr Unit. The pump will need to remain on until you are finished taking the backwash sample.

5. At 11:58 the BioStyr backwash cycle will be complete. At this point you are ready to take the BioStyr backwash sample. Note: From this point you will have 50 minutes to take the sample, drain the tank, clean the tank, and to prepare for the BioFor N backwash sampling.

6. To take the sample, confirm that the backwash recirculation pump is running and collect the backwash sample from the backwash sampling port located on the backwash recirculation line.

7. Once the sample is collected, **turn off the backwash recirculation pump** by unplugging it.

8. **Drain the backwash holding tank** by opining the valve on the backwash tanks main drain line and allow the liquid to drain to the sump located in front of the tank.

9. You are now ready to clean the backwash holding tank. Begin by closing the valve on the backwash tanks main drain line (the valve opened in step 8). Next, confirm that a hose is connected to the backwash tanks cleaning system and run the cleaning system for 5 minutes. After 5 minutes of wash down, drain the tank by plugging in the tank's sump pump. Once drained as far as the sump pump is capable, unplug the sump pump and repeat the wash down process two more times (a total of 3 times).

Visually confirm that the tank is clean. If required, repeat the wash down process as necessary.

10. When finished cleaning the backwash holding tank you are now ready to begin the BioFor N backwash collection process.

BioFor C

1. To perform the BioFor C backwash sample process follow steps 1 through 17 of the BioFor N backwash collection process noting that the backwash start time for the BioFor C unit is 13:30.

Download Column Pressure and Turbidity Data

2. Downloading column pressure and turbidity data from the BioFor and BioStyr units by following the directions listed on the "Pressure and Turbidity Data Download Instructions" in Exhibit F.. Once downloaded, e-mailing the data to Victor Occiano (Brown and Caldwell, vocciano@brwncald.com).

EXHIBIT H

SVI METHODOLOGY AND LOG SHEETS

2710 D. Sludge Volume Index

1. General Discussion

The sludge volume index (SVI) is the volume in milliliters occupied by 1 g of a suspension after 30 min settling. SVI typically is used to monitor settling characteristics of activated sludge and other biological suspensions.[1] Although SVI is not supported theoretically,[2] experience has shown it to be useful in routine process control.

2. Procedure

Determine the suspended solids concentration of a well-mixed sample of the suspension (See Section 2540D).

Determine the 30 min settled sludge volume (See Section 2710C).

3. Calculations

$$SVI = \frac{\text{settled sludge volume (mL/L)} \times 1000}{\text{suspended solids (mg/L)}}$$

4. Precision and Bias

Precision is determined by the precision achieved in the suspended solids measurement, the settling characteristics of the suspension, and variables associated with the measurement of the settled sludge volume. Bias is not applicable.

5. References

1. DICK, R.I. & P.A. VESILIND. 1969. The SVI—What is it? *J. Water Pollut. Control Fed.* 41:1285.
2. FINCH, J. & H. IVES. 1950. Settleability indexes for activated sludge. *Sewage Ind. Wastes* 22:833.

6. Bibliography

DONALDSON, W. 1932. Some notes on the operation of sewage treatment works. *Sewage Works J.* 4:48.

MOHLMAN, F.W. 1934. The sludge index. *Sewage Works J.* 6:119.

RUDOLFS, W. & I.O. LACY. 1934. Settling and compacting of activated sludge. *Sewage Works J.* 6:647.

2710 C. Settled Sludge Volume

1. General Discussion

The settled sludge volume of a biological suspension is useful in routine monitoring of biological processes. For activated sludge plant control, a 30-min settled sludge volume or the ratio of the 15-min to the 30-min settled sludge volume has been used to determine the returned-sludge flow rate and when to waste sludge. The 30-min settled sludge volume also is used to determine sludge volume index[1] (Section 2710D).

This method is inappropriate for dilute sludges because of the small volume of settled material. In such cases, use the volumetric test for settleable solids using an Imhoff cone (2540F). Results from 2540F are not comparable with those obtained with the procedure herein.

2. Apparatus

a. Settling column: Use 1-L graduated cylinder equipped with a stirring mechanism consisting of one or more thin rods extending the length of the column and positioned within two rod diameters of the cylinder wall. Provide a stirrer able to rotate the stirring rods at no greater than 4 rpm (peripheral tip speed of approximately 1.3 cm/s). See Figure 2710:1.

b. Stopwatch.

c. Thermometer.

3. Procedure

Place 1.0 L sample in settling column and distribute solids by covering the top and inverting cylinder three times. Insert stirring rods, activate stirring mechanism, start the stop watch, and let suspension settle. Continue stirring throughout test. Maintain suspension temperature during test at that in the basin from which the sample was taken.

Determine volume occupied by suspension at measured time intervals, e.g., 5, 10, 15, 20, 30, 45, and 60 min.

Report settled sludge volume of the suspension in milliliters for an indicated time interval.

Variations in suspension temperature, sampling and agitation methods, dimensions of settling column, and time between sampling and start of the determination significantly affect results.

4. Precision and Bias

Bias is not applicable. The precision for this test has not been determined.

5. Reference

1. DICK, R.I. & P.A. VESILIND. 1969. The SVI—What is It? *J. Water Pollut. Control Fed.* 41:1285.

EXHIBIT I

STANDARD OPERATION PROCEDURE FOR BIOMASS MEDIA SAMPLING AND ANALYSIS

Occiano, Victor

From: Freed, Tony [FreedT@USFilter.com]
Sent: Monday, February 02, 2004 10:22 AM
To: 'B&C:Victor Occiano'; 'B&C:Josh Newman'
Cc: Perry, Scott
Subject: FW: Media sampling method

Victor/Josh,
Below please find a discussion on Biostyr media sampling. We are still working on media testing protocols. Tony

> Confidentiality Note: This e-mail message and any attachments to it
> are intended only for the named recipients and may contain
> confidential information. If you are not one of the intended
> recipients, please do not duplicate or forward this e-mail message and
> immediately delete it from your computer.
>
> -----Original Message-----
> From: Thesing, Glenn
> Sent: Thursday, January 29, 2004 12:45 PM
> To: Freed, Tony
> Cc: Confroy, Joe; Kruger Biostyr Process
> Subject: Media sampling method
>
> Tony:
>
> Below is a description that Xavier gave me of how media samples have
> been obtained at the Paris research center. Let me know if you have
> questions.
>
> Thanks much.
>
> Procedure for Biostyr Media Sampling
>
> * Biostyr media samples are extracted from the side of the pilot unit
> through nozzles or ports in the column.
> * The water level in the column is first drained to a level below the
> point from which the sample is to be extracted. With the water level
> drained, the port can be opened with minimal risk of loosing a large
> amount of media. Note: if the water level is above the open port,
> media and water will spill quickly out of the column.
> * With the water level drained to the proper level, the 2" access port
> (or water sampling port) can be opened. The media bed will be exposed.
> * There is no special design for a media extraction tool. An empty
> pipe will be sufficient. 3/4" diameter or larger works best. (A long
> narrow scoop has also been used.) It is inserted through the port and
> into the media bed. Some media will be collected into the pipe.
> However, the media will not behave as a solid material (e.g. cohesive
> soil); so, the sample will not be a "core" sample that maintains the
> spatial arrangement of the actual media bed.
> * The pipe is withdrawn from the column, and the media sample can be
> removed with a plunging rod or by tapping the pipe.
>
>
>
> ________________________________
> Glenn Thesing, P.E.
> Process Manager - Biostyr
> Kruger, Inc.
> 401 Harrison Oaks Boulevard
> Cary, NC 27513
> (919) 677-8310 Phone

> (919) 677-0082 Fax
> thesingg@usfilter.com
>

>

Occiano, Victor

From: troy.holst@infilcodegremont.com
Sent: Monday, February 09, 2004 3:04 PM
To: vocciano@brwncald.com; SSen@BrwnCald.com
Cc: robert.kelly@infilcodegremont.com; hao.pham@infilcodegremont.com; christopher.tabor@infilcodegremont.com
Subject: Biofor media sampling information for Point Loma, CA pilot study

Delahaye et al IAWQ Biofilm Co...

biolite sampling.PPT (70 KB)

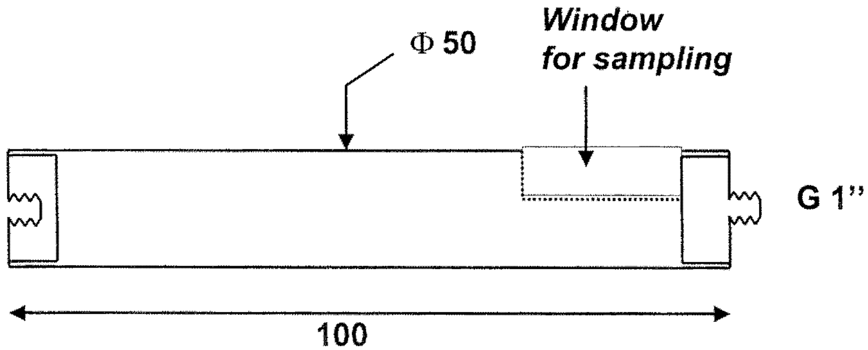
Victor & Seval,

Here's the paper which describes one method for measuring the biomass from the filter, and the drawing of the vertical sampling pipe.

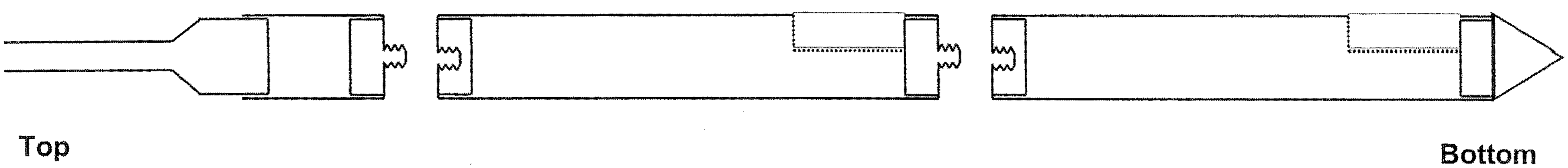
(See attached file: Delahaye et al IAWQ Biofilm Conf 1999.pdf)(See attached file: biolite sampling.PPT)

Troy Holst
Senior Project Engineer
Biological Systems Group
Ondeo Degremont, Inc.
2924 Emerywood Parkway
Richmond, VA 23294
Tel: 804-756-7747
Fax: 804-756-7643

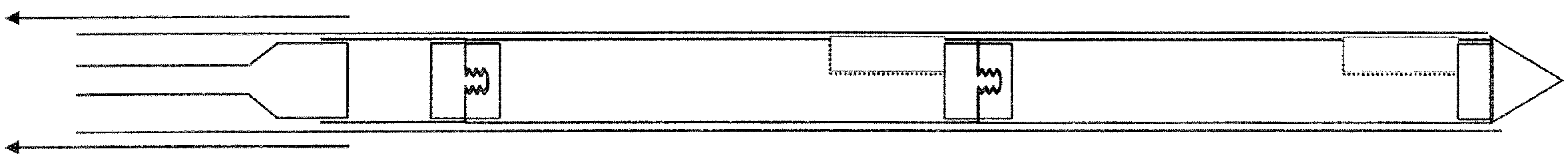
INTERMEDIATE UNIT



TERMINAL UNITS



PROCEDURE: insert the pipe during washing, take away slowly the flexible sheat (filtration sock) by the length of the window, let until full filling of the volume in each unit (10 min), remove carefully the pipe after full sampling, dismantle the pipe,



Presented at the International Association on Water Quality Conference on Biofilm Systems, New York, New York, October 17 – 20, 1999.

DISTRIBUTION AND CHARACTERISTICS OF BIOMASS IN PILOT-SCALE UPFLOW BIOLOGICAL AERATED FILTERS TREATING DOMESTIC WASTEWATER

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[**]*Environmental Biotechnology Laboratory, 212 Fralin Biotechnology Center, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA*
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ABSTRACT

Two pilot-scale upflow biological aerated filter (BAF) units were operated in series (carbon oxidation followed by nitrification) at a local domestic treatment facility. Media samples were removed along the length of the columns and the associated biomass was separated into either a detachable or strongly attached fraction. The biomass samples were analyzed biochemically, gravimetrically, and respirometrically. The detachable fraction accounted for 25 to 40 percent of the biomass in the beds. Although the biomass was predominantly protein, the carbohydrate to protein ratio (m/m) averaged 0.40 ± 0.12 g/g in the detachable fraction and was much lower (below 0.1 g/g) in the strongly attached fraction. Respirometry indicated that the strongly attached biomass had the potential to contribute up to 69 percent of the total respirometric activity of the system, demonstrating that the more easily detachable fraction contributed significantly to system activity. This fractional biomass structure facilitates rapid (within minutes) performance recovery of upflow BAF systems after backwash, and a conceptual model for this biomass structure is presented.

KEYWORDS

BAF, carbohydrate, protein, oligonucleotide probe, respirometry

INTRODUCTION

Fixed film-based wastewater treatment systems have been available for decades to treat domestic and industrial wastewaters. The most common examples in use around the United States today include trickling filters and rotating biological contactors. Recent developments in high capacity fixed film-based treatment systems and combined fixed film/suspended culture systems have occurred primarily outside of the United States, but have tremendous potential for application within the U.S. market. One technology that is new to the U.S. market is upflow biological aerated filtration (BAF). As part of an effort to learn more about this technology, a pilot-scale two-column (carbon oxidizing C column followed by nitrifying N column) Biofor® BAF plant was operated for over 10 months at the Peppers Ferry Regional Wastewater Treatment Facility located in Radford, Virginia. The columns were operated over a range of substrate and hydraulic loading conditions in order to assess the performance of the system. Treatment performance was characterized based on cBOD and ammonia removal efficiencies and is reported elsewhere (Love et al., 1999). Additionally, the influence of hydraulic loading on system performance (Husovitz et al., 1999) and on the distribution of ammonia oxidizing bacteria (AOB) based on small subunit (SSU) 16S rRNA probing techniques (Gilmore et al., 1998) were also determined. During the course of operating the pilot-scale BAF columns, it became clear that our initial concept that the biomass within the columns existed as a biofilm surrounding media was too simplistic. An effort was undertaken to characterize the composition and function of the biomass in the column system in order to improve our understanding of how BAFs function at the microscale. This manuscript addresses those experiments and concludes by suggesting a conceptual model for biomass within a BAF system that may serve as the basis for subsequent experiments and computational modeling efforts.

METHODS

System setup and operation

Two pilot-plant BAF systems were provided by Infilco Degremont, Inc. (Richmond, VA) and located at the Peppers Ferry Regional Wastewater Treatment Facility (PFRWTF) in Radford, VA. The two columns were operated in series: the first carbon oxidation stage (C column) received primary effluent generated by the full-scale treatment plant, and the effluent from this column was fed to the second nitrification stage (N column). The C and N columns were 0.61 m in diameter and contained 3.9 and 3.7 m of clay-based media, respectively. The media specific surface area averaged 1,400 m^2/m^3, had a density of 1.5 g/cm^3, and an average porosity within the columns of 0.4. Both columns were fitted with 4 sampling ports evenly distributed along the depth of the media. The sample ports accommodated a hollow steel sampling tube which could be shoved across any fraction of the column diameter. Media samples were obtained for biomass measurements by coring across the entire column diameter. Composite liquid samples were collected for dissolved chemical analysis by collecting equal volumes of liquid at four equidistant points across the diameter of the column. The columns were regularly backwashed (every 12 hours for the C column and every 24 hours for the N column) using effluent collected from the N column. A range of hydraulic and substrate loadings were applied to the columns over the course of the study. For the data shown below, the hydraulic loading to the C and N columns were 8.2 and 7.1 m/h, respectively, unless otherwise noted.

Preparing biomass fractions

Biomass-containing media samples that were subsequently analyzed using gravimetric, biochemical and respirometric methods were obtained from the columns after draining the bed. The lower (0.6 m along the media bed) and middle (2.2. m along the media bed) ports were sampled, chilled at 4°C and returned to the Environmental Engineering Laboratory for analysis at room temperature as soon as possible after collecting samples. Liquid was collected from the same ports prior to draining the columns and was subsequently used as dilution water. Once in the lab, 80 g of wet media and turbid surrounding liquid was placed in a 1 liter square bottle and 500 ml of dilution water was added. The bottle was slowly turned end over end once in a hand crank device. The liquid was removed. Another 500 ml of dilution water was added and the bottle was turned 60 revolutions end over end with the hand crank for 1 minute. The liquid was removed. The biomass present in these two liquid samples are hereafter termed the ***detachable fraction***. The biomass remaining on the media after this treatment is hereafter termed the ***strongly attached fraction***.

Analytical Procedures

Volatile suspended solids (VSS) were measured in liquid samples using a 1.5 μm glass fiber filter (Whatman Inc., Clifton, NJ) according to Standard Methods (APHA, 1995). For strongly attached biomass samples, the biomass-coated media was dried at 105°C overnight, weighed, and then burned in a 550°C muffle furnace for 30 minutes. A dessication chamber was used to minimize water absorption into the media during weighing; despite this effort, the highly hygroscopic media tended to absorb water rapidly, leading to a tendency to slightly underestimate VSS results. To standardize measurements on a per mass of media basis, the media was weighed as wet weight or dry weight (less than 1 percent difference between the two measures) and the the result was expressed on a per g media basis.

Protein was determined using the bicinchoninic acid assay (Sigma Chemicals, St. Louis, MO). Liquid samples were processed according to the kit instructions after hydrolysis of the whole sample in 1 M NaOH at 100°C for 5 minutes. This hydrolysis method was shown to produce equal or higher protein concentrations than sonication for suspended culture samples, and was considered adequate. Absorbances were read at 562 nm with a spectrophotometer (Beckman Instruments, Fullerton, CA). Cells in the detachable fractions were not pelleted prior to alkaline hydrolysis to be consistent with treatment of the media-bound strongly attached biomass. Protein levels in the dilution water were subtracted from values obtained for the detachable fraction. Protein was determined for media-bound strongly attached biomass by adding a known mass (2 to 3 g) of media into a glass test tube with 5 ml of 1 M NaOH. Samples were hydrolyzed at 100°C for 30 minutes. Bovine serum albumin was used as the protein standard, and all standards were prepared in a 1 M NaOH solvent. Carbohydrates were determined using the phenol-sulfuric acid method (Dubois et al., 1956) with glucose as standard. Carbohydrate was determined for strongly attached biomass by using the supernatant from the NaOH hydrolysis step described above for protein analysis. The phenol-sulfuric acid method was used as before, except that glucose standards were taken through the base hydrolysis procedure like the samples. Blanks and standards were analyzed in the presence of clean media to confirm that the media did not interfere with protein or carbohydrate measurements.

Liquid samples of detachable biomass were used for specific oxygen uptake rate (SOUR) measurements in 300 ml BOD bottles without further dilution. SOURs were measured with media-bound strongly attached biomass by adding a known mass (15 to 20 g) of media in a BOD bottle and adding dilution water to a final volume of 300 ml. Assays were oxygenated with an aquarium air pump connected to a diffuser. After oxygenation, the decrease in oxygen concentration was recorded using a DO probe equipped with a mixer at the base of the probe tip (YSI, Inc., Yellow Springs, Ohio). Some SOUR assays were spiked with additional electron donor: a synthetic biogenic organic carbon mixture (Bailey and Love, 1999) was added to achieve a starting concentration of 330 mg/L as COD for C column samples, or an ammonia chloride solution was used to achieve a starting concentration of 20 mg/L as nitrogen for N column samples. All SOUR assays were conducted in a constant temperature room (18 °C) which remained at a temperature that was within 2°C of the wastewater temperature in the field. The SOUR test could not be conducted on site due to uncontrolled outside temperatures, which varied from day to day.

COD was analyzed according to Standard Methods (APHA, 1995). All reported errors represent plus or minus one standard deviation.

RESULTS AND DISCUSSION

Distribution of Biomass Between Fractions

The amount of biomass as VSS in the two columns is rather dense, the majority of which exists in the strongly attached state, but the average amount of biomass decreases with length along the columns. The average amount of biomass in the C and N columns was 11.1 ± 1.8 and 6.5 ± 1.0 mg VSS/g media, respectively. These values are close to the value of 6.9 mg VSS/g media reported by Amar et al. (1986) who used clay media in an upflow BAF treating primary wastewater. These measured values yield an apparent VSS concentration of 9,990 and 5,850 mg per liter of total C and N reactor volume (rock plus void space volume). This demonstrates the degree to which the BAF systems maintain a higher density of biomass than conventional activated sludge treatment systems (typical mixed liquor VSS concentrations range from 1,300 to 2,500 mg/L) (WEF, 1991). Figure 1 demonstrates how the biomass was distributed within the C and N columns. The strongly attached biomass represented 60 to 75% of the total biomass in the columns. As would be expected, the average amount of biomass was greatest at the bottom (inlet) of the C column where the cBOD loading was greatest, and was least at the outlet of the N column, where nitrification was occurring in the absence of significant amounts of cBOD.

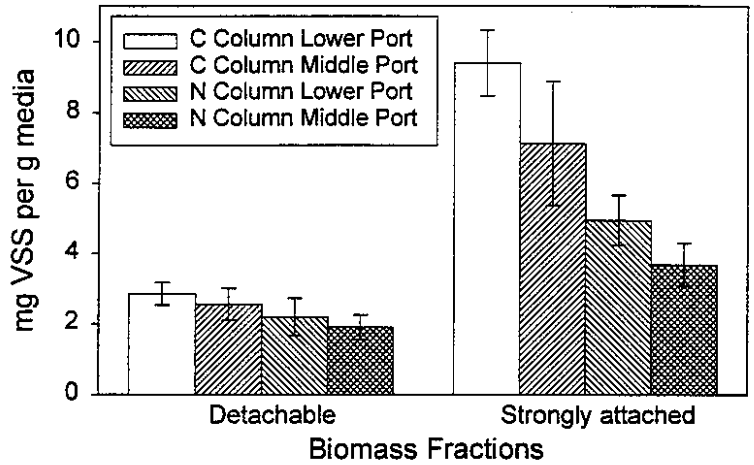

Figure 1. Density of VSS in BAF samples for each biomass fraction, averaged per port and per column.

Although this trend was observed with both fractions of biomass, it was only significant for the strongly attached fraction.

Protein and Carbohydrate Composition of Biomass Fractions

Total (cells plus exocellular polymeric substances, EPS) measurements of protein and carbohydrate in the biomass indicated that protein was the predominant component of the two, but the ratio of carbohydrate to protein was significantly different for the different fractions of biomass. As shown in Figure 2, the relative amount of carbohydrate to protein was much greater in the detachable fraction than in the strongly attached fraction. The ratio was not significantly different between the C and N columns for the detachable fraction and averaged 0.40 ± 0.12 (n=35). The value of this ratio was significantly lower for the strongly attached fraction. Values for the carbohydrate:protein ratio differ significantly in the literature and depend to a significant degree on the type of biomass sampled and the manner in which samples are collected and processed. Frølund et al. (1996) reported a carbohydrate:protein ratio for activated sludge (cells + EPS) ranging from 0.35 to 0.55, which is within the range of the values reported here for the detachable biomass fraction. The relatively larger amount of protein in the strongly attached fraction may reflect the relatively larger portion of the biomass that was comprised of EPS, which is believed to be primarily protein in biofilm systems (Nielson et al., 1997). On the other hand, the data suggest that there are significantly higher levels of carbohydrate present in the detached biomass relative to protein. This contrast in carbohydrate to protein ratio between the strongly attached and detachable biomass fractions indicates that perhaps the polysaccharides are synthesized to different degrees between the two fractions, or the polysaccharides may not be of the same type in the two different fractions. The method used to quantify the amount of carbohydrate is known to be sensitive to selected types of sugars and not others (Horan and Eccles, 1986). Figure 2 also shows that there was a significant difference in the carbohydrate:protein ratio between the C column biomass (0.020 ± 0.017, n=9) and the N column biomass (0.091 ± 0.028, n=9) for the strongly attached fraction. The biomass in the C column contained primarily heterotrophic bacteria because cBOD removal was featured, whereas the N column contained a significant autotrophic nitrifier community (Gilmore et al., 1998). Similarly, Lazarova et al. (1998) reported a difference in the carbohydrate:protein ratio in a three phase circulating bed reactor where the ratio for a nitrifying system ranged from 0.16 to 0.22, while the ratio for a combined carbon oxidation and nitrification system ranged from 0.30 to 0.71. Our values are lower on average. Additionally, strongly attached biomass in the N column had a higher ratio than the strongly attached biomass which contained more heterotrophic bacteria. These differences between studies may reflect the wastewater used, which in our case was primary effluent from a domestic wastewater treatment plant, or the nature of the carbohydrates produced by nitrifying bacteria relative to

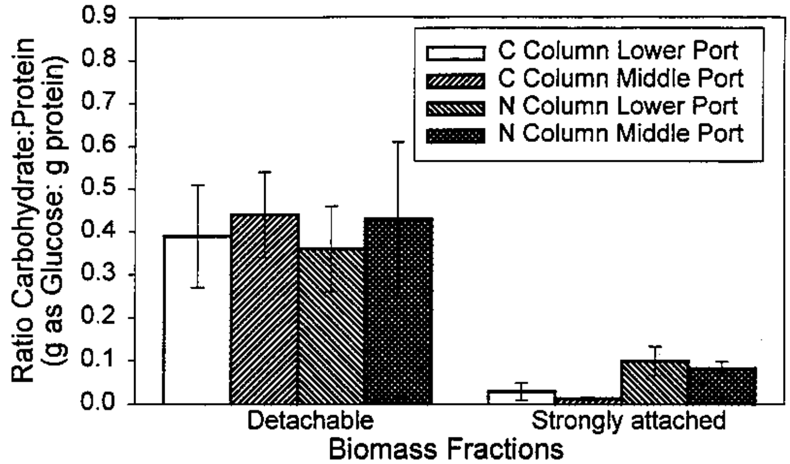

Figure 2. Ratio of carbohydrate to protein for different biomass fractions, averaged per port and per column.

heterotrophic bacteria.

Specific Oxygen Uptake Rates of Biomass Fractions

Specific oxygen uptake rates (SOUR) showed that there was a significant contribution to respirometric activity by both the detachable and strongly attached biomass fractions. As shown in Table 1, the strongly attached biomass reflected a lower SOUR than the detachable biomass. This may reflect the presence of a substrate or dissolved oxygen mass transfer limitation incurred during the respirometric assay. It may also be due in part to the higher level of protein per gram VSS measured in the strongly attached biomass (data not shown). The fact that the C column showed a greater difference between detachable and strongly attached biomass than the N column is consistent with the suggestion that the assay was mass transfer limited given the larger amount of biomass associated with the strongly attached biofilm in the C column (8.40 ± 1.74 mg VSS/g media, n=9) than in the N column (4.39 ± 0.92 mg VSS/g media, n=9). The detachable biomass reflected a decrease in average SOUR for sample ports further along each column. This trend was significant for the N column. Since the dilution water used to determine SOURs was also collected from the same port that the biomass was collected from, it was assumed that these lower rates might reflect substrate limitations. Consequently, SOUR assays were also conducted by spiking with supplemental readily biodegradable COD (C column samples) or ammonia (N column samples). As shown in Table 1, although the data suggest that there may have been a slight substrate limitation in the C column respirometric samples, there was no evidence for such a limitation in the N column and the general trends observed with the unspiked SOUR tests were also seen with the spiked SOUR tests.

Most current conceptual models of BAF systems consider the biomass to be characterized as a fixed film (or biofilm). Our data show that there are significant differences between the strongly attached biomass fraction (probably reflective of a biofilm) and the detachable biomass fraction. Additionally, our data show that a significant fraction of respirometric activity is due to the loose, detachable fraction. Once the SOUR data are converted to units of oxygen uptake rate per g media (to reflect the respirometric activity incurred per unit volume for each fraction of biomass), the data show that 31 to 44 percent of the activity is contributed by the detachable fraction (see Figure 3). We envision this biomass as being loose material that is trapped in the pores of the bed as opposed to the strongly attached, fixed biomass.

Table 1. SOUR (mg O_2/g protein – minute) data for biomass fractions spiked with either dilution water from the same port, or with readily biodegradable COD or ammonia. Ratios of dilution water: spiked SOUR results are also given.

	C column		N column		Energy
Port location	0.6 m	2.2 m	0.6 m	2.2 m	Source
Detachable	1.5 ± 0.55	1.09 ± 0.32	1.62 ± 0.36	0.75 ± 0.26	Dilution water
Strongly attached	0.38 ± 0.07	0.24 ± 0.05	0.67 ± 0.26	0.68 ± 0.46	Dilution water
Detachable	1.89 + 0.76	1.31 + 0.35	1.68 + 0.37	0.68 + 0.35	COD or Ammonia
Strongly attached	0.29 + 0.11	0.26 + 0.091	0.57 + 0.21	0.54 + 0.24	COD or Ammonia
	Spiked:Dilution Water Ratio				
Detachable	1.24 + 0.31	1.23 + 0.17	1.02 + 0.07	1.02 + 0.10	
Strongly attached	0.84 + 0.23	1.14 + 0.14	0.95 + 0.04	0.92 + 0.25	

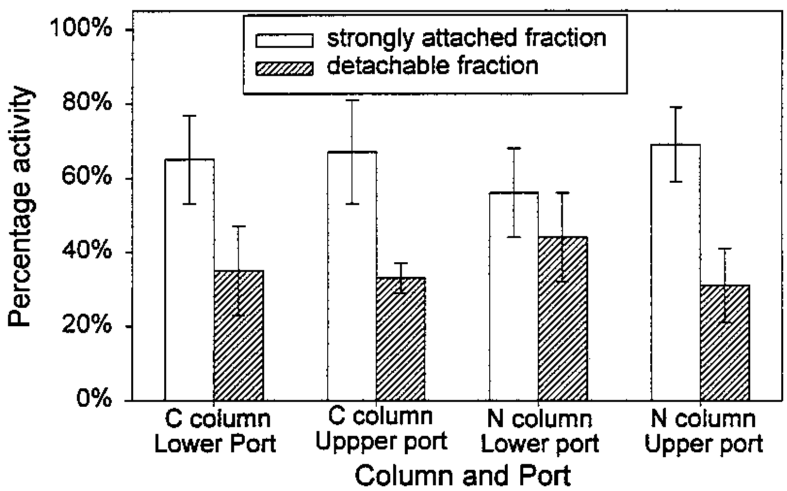

Figure 3. Distribution of respirometric activity between biomass fractions. The respirometric activity was measured with same-port dilution water and percentages were determined based on oxygen uptake rate (mg O_2/min) per g media.

Backwash Recovery

BAFs have been reported to recover quickly from backwashes without the lag time that is often encountered when active outer layers of biofilms are sheared off (Amar et al., 1996). Figure 4 shows a typical profile for soluble COD and total COD during and just after a backwash for the C column. The data show that the system performance within 5 minutes of the end of the backwash reflects the average system performance tracked by a composite sample over an entire cycle. Such quick system recovery is due to high levels of activity by both the detachable and strongly attached biomass fractions that remain. Respirometric data show that there is no significant difference in SOUR for the C and N columns as measured at the beginning (within 10 minutes of backwash) and end of a cycle (data not shown).

Modified Conceptual Model of Biomass in a BAF System

Figure 5 reflects our current conceptual model for how biomass moves through an upflow BAF system. The detachable biomass is believed to move through the system more rapidly than the strongly attached biomass, but the latter contributes to the former as it is sheared off during backwash events. As BAF systems are not fluidized during backwash, a substantial amount of detachable or recently sheared strongly attached biomass remains behind in the interstices of the media. Additionally, backwashing may encourage redistribution of sheared and detachable biomass throughout the bed. It is suggested that these features assist with the rapid recovery of BAF systems. Although a modeling effort was not part of this project, the data suggest that mechanistically-based BAF models and future experimental efforts should be framed around two distinct biomass fractions which may represent different mass transfer characteristics.

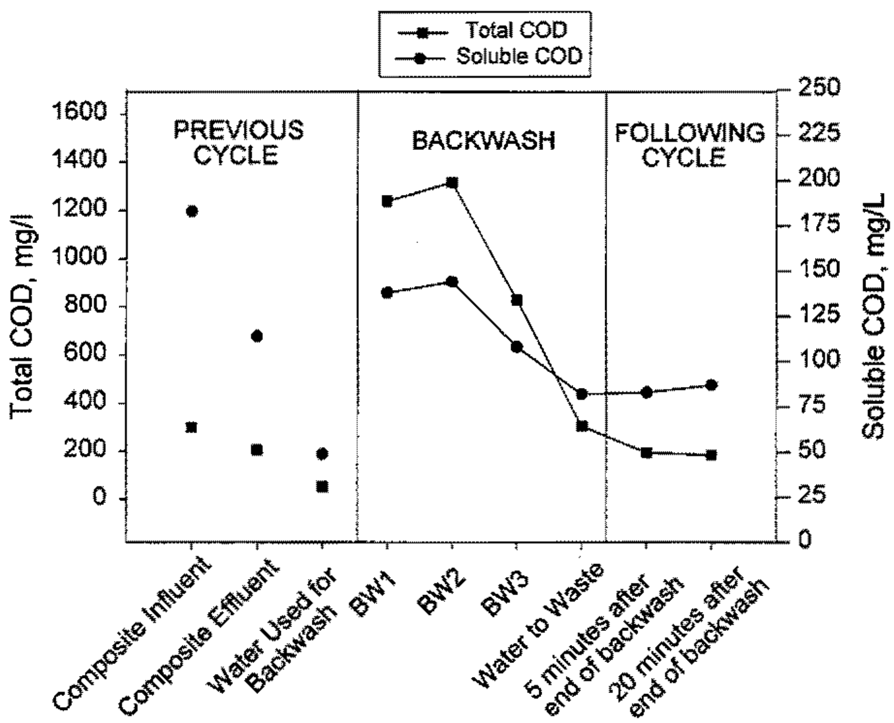

Figure 4. Evolution of total and soluble effluent COD during a typical backwash of the C column. The concentrations of COD in the composite influent, C column effluent, and N column effluent (which is used to backwash) during the previous cycle are provided for comparison.

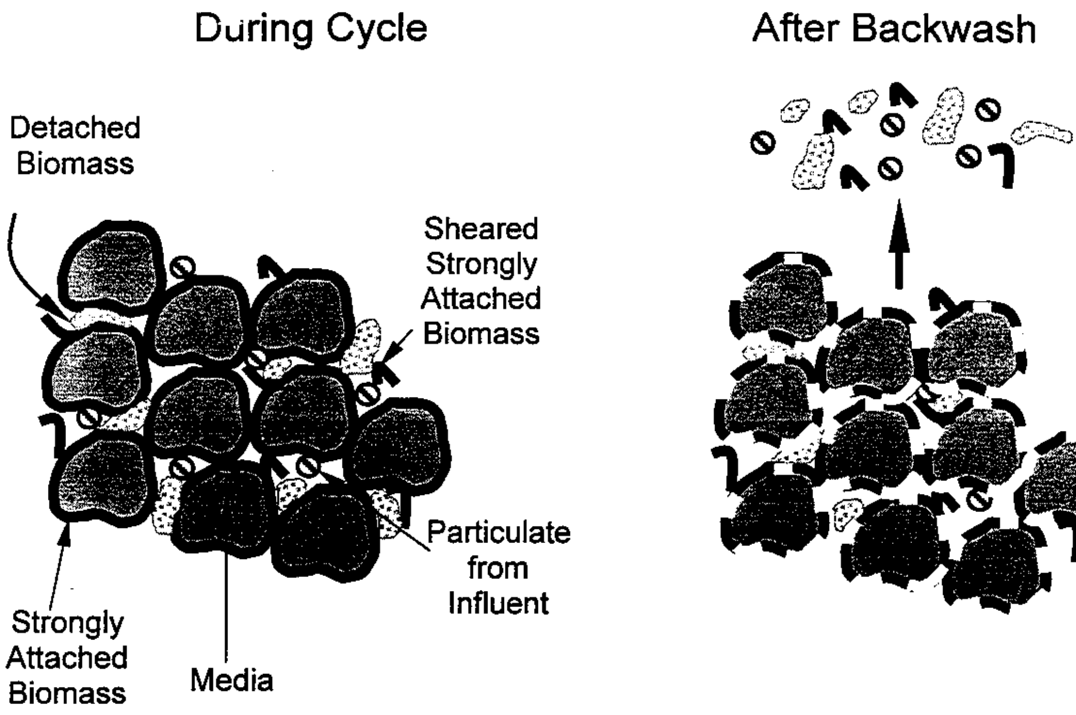

Figure 5. Conceptualization of biomass and designated fractions during cycle and shortly after backwash.

CONCLUSIONS

This study showed that the biomass in upflow BAF systems is composed of a strongly attached fraction which can be characterized as a biofilm fraction, and a detachable fraction which is loosely contained in the interstices of the media. The strongly attached fraction comprises the majority of the biomass in the system, but the detachable fraction is a significant component in terms of mass and activity. The biochemical nature of the fractions is significantly different in that the strongly attached biomass contains much more protein relative to carbohydrate than the detachable fraction, which probably reflects the larger amount of exopolymeric material present in the strongly attached fraction. However, this may also influence differences in the transport of substrate and oxygen into the two biomass fractions, with the strongly attached biomass being more transport limited. Data show that BAF systems return to highly efficient performance within minutes of ending a backwash event. This feature can be explained by the fractional nature of the biomass. Both fractions are removed to some degree during backwash events, and some fraction of the strongly attached biomass is sheared and joins the detachable fraction. However, it is believed that a significant feature of backwashing involves the redistribution of detachable biomass throughout the length of the media bed so that the full bed is responsive to wastewater flowing through it from the beginning of a cycle.

ACKNOWLEDGEMENTS

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EXHIBIT J

CONTINUOUS TURBIDITY METER LOG SHEETS

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study

Continuous Turbidimeter Log

Date Inserted	Date Removed	Location	Analyst

EXHIBIT K

BAF O&M MANUAL

Krüger

O & M Manual
For Biostyr Pilot System

Point Loma WWTP, San Diego, CA

Prepared by:
Kruger Inc.
401 Harrison Oaks Blvd.
Cary, NC 27513

January, 2004

1.0 PILOT SYSTEM CONPONENTS

The Biostyr® process is a biological reactor with upflow filtration through a submerged and floating media made of polystyrene beads. The media provides surface for attachment of biofilm, which achieves biological treatments of soluble contaminants and acts as filter for suspended solids removal.

The Biostyr pilot system for the Point Loma facility provides carbonaceous BOD and TSS removal following chemical enhanced, high-rate, primary clarification. The influent water is pumped from a feed tank up to a standpipe. The standpipe provides elevation head for gravity flow through the filter. In filtration, flow is upward through the media bed. Treated water exits the top of the column and flows into a backwash supply tank.

Due to the TSS retention and the biological activity, the filter builds up hydraulic resistance and needs to be backwashed periodically. The backwash is accomplished by down-flow flush using the treated water. The waste backwash water runs into a floor drain.

When the system is not treating the feed for a short period of time, intermittent aeration is provided to the system to keep biomass alive. Such operation of the system is defined as idle.

An air grid is located below the filter bed. The air grid supplies the oxygen needed for the biological activities (BOD removal only). The air grid is also used to inject scouring air during a backwash period and to inject air intermittently to the filter during the idle period. The air is provided from an on-site compressed air system.

This section provides an overview of the key components that comprise the pilot system and summarizes how they contribute to and operate within the system. Specific operation and maintenance information for each piece of equipment, if applicable, may be found in the relevant Mechanical O&M manual for that equipment.

1.1 COMPRESSED AIR SYSTEM

- Description: A 2.0 HP air compressor system includes 80-gallon vertical tank, auto tank drain and refrigerated air dryer. The capacity is 6.0 SCFM at 100 PSIG.

- Use: 1) To supply air for the filter’s process and backwash needs; 2) To provide compressed, dried air for use by the pilot system valve actuators.

1.2 BACKWASH STORAGE PUMP

- Description: Two (2), constant-speed, 3 HP, pumps are provided, one as spare. Spare pumps are mounted. Conduit and wire are connected to the pumps. However, wires are not terminated in control panel and are to left coiled and loose in panel.

- Use: The pump is used to transfer the treated water from the backwash supply tank back to the top section of the column to supply flush water used during backwashes. The pump is controlled automatically by the pilot control system. Control is based on the BAF backwashing routine and level switches in top section of the column.

1.3 AIR GRIDS

- Description: Two, 1 inch, Schedule 5, 316SS pipes are installed inside column above the feed pipe. Each pipe is perforated with two 0.16 inch (4.0 mm) orifices.

- Use: Distribution of process and backwash air into the media. Air from the compressor is injected into the column through the four orifices.

1.4 PROCESS VALVES

- Description: Various butterfly with pneumatic actuators and ball valves. See Drawing 385PFD01 in Appendix A for the locations of the valves.

- Use:
  1) Automatic Butterfly Valves - Routing of air and water streams associated with the BAF process. All actuated valves are controlled by the pilot control system. Control interface is built into the pilot SCADA system. In automatic operation, valves are operated by the pilot control system without intervention from the operator. Valves may be placed in manual mode and operated independently from the automatic control scheme. Operation may then be through manual control at the SCADA screen, through the local solenoid, which supplies air to each actuator, or by declutching the actuator and manually moving the valve disk.
  2) Manual Ball Valves - The 5 manual ball valves are used for isolation purpose.
  3) Manual Butterfly Valves – The two manual butterfly valves are used to control backwash water supply rate and backwash flush rate.
  4) Check Valves – The three check valves are used to block water flow backwards to damage either the two pumps and the air compressor.

1.5 TUBE SHEET AND NOZZLES

- Description: A 25.44-inch diameter stainless steel plate separates the top section from the main section of the column. The nozzles are molded polypropylene construction. Top end is threaded and capped with four notches to accept the special nozzle installation tool. The nozzles are screwed on to the tube sheet. Nozzles must only be installed or removed with the nozzle installation tool. A total of 16 nozzles are installed onto the tube sheet for this pilot system.

- Use: The nozzles allow the passage of treated water upwards across the tube sheet while retaining the media below the tube sheet within the main section of the column.

1.6 BIOSTYRENE MEDIA

- Description: Installed in the pilot column. Nominal media bed depth 11’-6”. Spherical polystyrene beads. Average diameter 5.0 mm. Bulk density of clean, dry media approximately 50 g/L. Unused media is pure white. Once seeded with biomass, the media (i.e. the biofilm surrounding the beads) will appear light to dark brown in color.

- Use: The media provides the surfaces on which the biomass attaches and acts as filter for TSS removal. The high specific area of the bulk media yields a high concentration of bacteria.

1.7 PRESSURE PORT

- Description: One pressure port is located near the bottom of the column. Stainless steel 1/2" diameter pipe that extends from the inside of the column. A strainer is provided for each port to prevent the leak of media.

- Use: A pressure transducer and transmitter is attached to the port to monitor water head within the column.

1.8 MEDIA SAMPLING PORTS

- Description: Two media sampling ports are located within the media bed – one at 4 ft from the nozzle deck and the other at 8 ft from the nozzle deck. Stainless steel 2" diameter pipe that extends from the inside of the column are threaded to seal.

- Use: Media sampling.

1.9 SAMPLE PORTS

- Description: The column is equipped with a total of 7 sample ports. The ports are evenly distributed along the main section of the column. Stainless steel 1/2" diameter pipe that extends from the inside of the column. A strainer is provided for each port to prevent the leak of media. For this application with 11.5 ft media bed in the column, 4 of the 7 ports will be located within the media bed.

- Use: Profile sampling.

1.10 FEED PUMPS

- Description: Two 0.75 HP, variable speed, pumps are provided – one as spare. Spare pumps are mounted. Conduit and wire are connected to the pumps. However, wires are not terminated in control panel and are to left coiled and loose in panel.

- Use: Transfers the water to be treated from the inlet Pump Station to the 4" inlet standpipe.

1.11 INLET STANDPIPE

- Description: A 4-inch standpipe provides gravity head to force influent water through media beds.

- Use: Serves to simulate the gravity feed of the influent to the column.

1.12 FEED / BACKWASH PIPES

- Description: A 4" stainless steel pipe is placed onto the column floor. 18, 0.5"-diameter holes are provided near the bottom of the pipes to allow influent and backwash water to pass.

- Use:
  1) As feed system: passes influent from the feed pipe to the inside of the column during filtration.
  2) As backwash system: collection of flush water during backwash and transportation of the water to the waste backwash storage tank.

1.13 EFFLUENT SECTION OF THE COLUMN

- Description: The column top section above the nozzle deck is made of 36-inch stainless steel pipe. Treated water flows through the media and nozzles into this section, and then overflows through an effluent weir to the backwash supply tank.

- Use: The top section is used to 1) provide the gravity force for backwashes and 2) store the effluent water for installing analyzers. An effluent weir is installed to maintain a minimum depth of water.

1.14 BACKWASH STORAGE TANK

- Description: Treated water flows from the column into the backwash water storage tank, and then overflows to the plant drain system.

- Use: This tank is used to store the treated water for backwash supply. A pump is provided to pump the water back to the top section of the column, and then flush down the media by gravity (backwash rinse phase).

1.15 SIGHT GLASS ASSEMBLY

- Description: Four sight glasses are installed on the column.

- Use: Visual observation of the media bed during filtration and backwashes.

2.0 FUNCTIONAL DESCRIPTIONS OF CONTROL COMPONENTS

2.1 SUMMARY

The process & instrumentation diagrams (P&IDs) are presented in Appendix A for reference. Tables 1 and 2 summarize the control components of the pilot system.

Table 1 Control Components (Equipment)

Equipment	Function
Variable Speed Feed pump	Lift feed to the influent standpipe (VFD)
Feed Valve	Feed Control Valve (Open/Close)
Air Mass Flow Controller	Airflow control (Modulating)
Backwash Supply Pump	Supply treated water during backwash (Constant speed – on/off)
Backwash Flush Valve	Backwash Control Valve (Open/close)
Backwash Supply Tank Mixer	Keep solids in suspension (On/off)

Table 2. Control Component (Instruments).

Instrumentation	Type of signal
Influent Flow Meter	Analog
Pressure Transmitter	Analog
Effluent DO Analyzer	Analog
Effluent pH Analyzer	Analog
Backwash Flush Flow Meter	Analog
Column Low Level Switch	Discrete
Column High Level Switch	Discrete
Backwash Storage Tank Low Level Switch	Discrete
Backwash Storage Tank High Level Switch	Discrete

2.2 INFLUENT (WATER) FLOW METER

Type: Analog
Range: 0-30 gpm
Alarms: None.
Indication: Local and SCADA.
Control: Used in flow control loop to maintain the influent flow setpoint. Flow meter output is used by PLC to make adjustments to the influent pump speed. See Section 9 for discussion of influent flow setpoint.

2.3 PRESSURE INSTRUMENT

Type: Analog
Range: 0-400” WC, typical.
Alarms: None directly. Data is used in PLC calculations to generate alarms for headloss.
Indication: Local and SCADA.
Control: Output is used in process control calculations for column headloss and clogging. Headloss and clogging values are used for system control and alarms. See Section 3 for calculations and process control parameters.

2.4 EFFLUENT DO ANALYZER

Type: Analog
Range: 0-15 mg/L.
Alarms: None
Indication: Local and SCADA.
Control: Output is used in process airflow control loop to maintain the effluent DO setpoint. DO meter output is used by PLC to make adjustments to process airflow rate. See Section 8 for discussion of process airflow control modes.

2.5 EFFLUENT pH METER

Type: Analog
Range: 1-14
Alarms: None
Indication: Local and SCADA.
Control: None. Data is used for monitoring only.

2.6 COLUMN LOW LEVEL SWITCH

Type: Discrete
Range: n/a
Alarms: None
Indication: None
Control: When the column is in backwash mode, and the water level is lowered to the level of the switch (~20" above the nozzle deck), the backwash supply pump is started. If the column is <u>not</u> in backwash mode, the switch has no effect.

2.7 COLUMN HIGH LEVEL SWITCH

Type: Discrete
Range: n/a
Alarms: None
Indication: None
Control: When the system is in backwash mode, and the water level is at or higher than the level of the switch (level with the effluent weir), the backwash supply pump is stopped. If the system is <u>not</u> in backwash mode, the switch has no effect.

2.8 BACKWASH FLUSH FLOW METER

Type: Analog
Range: 0-200 gpm
Alarms: None.
Indication: Local and SCADA.
Control: None. Used for monitoring only.

2.9 BACKWASH SUPPLY TANK LOW LEVEL SWITCH

Type: Discrete
Range: n/a
Alarms: When low-level switch activated.
Indication: None.

Control: When low level is reached, backwash supply pump is stopped and backwash is interrupted.

2.10 BACKWASH SUPPLY TANK HIGH LEVEL SWITCH

Type: Discrete
Range: n/a
Alarms: None
Indication: None.
Control: When high level is reached, backwash is permitted (See Section 7 for Backwash Permissive conditions).

2.11 FEED PUMP

Operation: Variable Speed
Range: 2-30 gpm
Alarms: None
Indication: Speed and manual/auto status in SCADA.
Control: Speed is adjusted to maintain flow setpoint. Refer to Section 9 for a description of the feed flow control and setpoint.

2.12 FEED VALVE

Operation: Open/Close
Range: n/a
Alarms: Failure to open or close time out alarm.
Indication: Open status, close status in SCADA.
Control: In automatic operation, when the influent pump is running, the valve is open. The valve closes during a backwash for the duration of the backwash. It reopens when pumping resumes.

2.13 MASS AIRFLOW CONTROLLER

Operation: Modulating
Range: 0-100% Open
Alarms: None.
Indication: Local and SCADA display of flow rate.
Control: The airflow control valve is coupled with an airflow meter in an off-the-shelf unit: the Alicat gas mass flow controller. The PLC sends and airflow setpoint signal (4-20 mA) to the unit, which then self-adjusts by it's own internal PID loop to meet that setpoint. The airflow setpoint provided by the Biostyr PLC. Refer to Section 8 for a description of how the airflow setpoint is determined.

2.14 BACKWASH FLUSH VALVE

Operation: Open/Close
Range: n/a
Alarms: Failure to open or close timeout alarm.
Indication: Open status, close status in SCADA.

Control: This valve is opened at the beginning of each backwash flush. It is closed when the flush is completed. Refer to Section 7 for a description of backwash sequences and timers.

2.15 BACKWASH SUPPLY PUMP

Operation: Constant Speed
Range: 120 gpm
Alarms: None
Indication: Start/stop/auto status in SCADA system.
Control: Starts when the column low-level switch is activated for the system in backwash. Stops when the same column's high-level switch is activated. In automatic operation, the pump only starts/stops while the system is in backwash mode.

2.16 BACKWASH SUPPLY TANK MIXER

Operation: Constant Speed
Range: n/a
Alarms: None
Indication: Start/stop/auto status in SCADA system.
Control: Runs continuously in auto mode.

3.0 PROCESS CONTROL PARAMETERS

This section introduces process control parameters calculated based on on-line pressure measurements.

3.1 FILTRATION HEADLOSS

Filtration headloss across a filter is defined as the difference in water level between the inlet chimney and the effluent weir. The water level in the inlet chimney is measured by the pressure transducer below each air grid (or at the column bottom). The water level in the effluent is not measured. Instead, it is assumed constant and equal to the level of the effluent weir. The filtration headloss across a filter ($\Delta P(t)$) is calculated continuously by the following formula:

$$\Delta P(t) = P_1(t) - dE \quad \text{in feet of Water Column (WC)} \qquad (1)$$

Where:

$P_1(t)$: Pressure measured by the pressure transmitter at the bottom of the column at time t in feet of WC;

dE: Elevation difference between the effluent weir and the pressure transducer of the level transmitter in feet of WC; and

$\Delta P(t)$: The calculated headloss across the filter at time (t) in feet of WC.

There are two setpoints using the filtration headloss of a filter (ΔP):

1. High level setpoint (ΔP_{REF}): leads to a mini backwash;
2. Very high level setpoint (Δp_{MAX}): leads to alarm and manual idle position. The operators need to determine cause and may perform an aggressive backwash.

3.2 PERCENT OF CLOGGING

Percent clogging is an indicator value. Used to estimate the blocking effect of sludge deposits in the media. Headloss alone is insufficient to evaluate the clogging effect by sludge deposit, since headloss is also a function of superficial velocity. The effect of superficial velocity is accounted for in the percent clogging calculation by defining the percentage of clogging (d) as follow:

$$d(t) = 100 \times \left(\frac{V_{\max}}{V(t)} \right)^{\alpha} \times \frac{\Delta p(t)}{\Delta p_{\max}} \qquad (4)$$

Where:

t: Generic time

d(t): Clogging percentage (0 -100%);

α: Velocity correction parameter between 0.0 to 1.0;

$\Delta P(t)$: Measured headloss across the filter at t in feet of WC;

V_{max}: Maximum filtration velocity in ft/h; and

V(t): Filtration velocity at time t in ft/h.

Two set points are assigned based on percentage of clogging to control the filter operation:

- High level clogging setpoint (d_{REF}): lead to a mini backwash; and
- Very high level clogging setpoint (d_{MAX}): lead to alarm and manual idle position. The operators need to determine cause and may perform an aggressive backwash.

When α approaches 1.0, the the percent of clogging calculation is sensitive to velocity, meaning that a backwash could be launched with a low velocity. When α approaches 0.0, the velocity component is subordinate, so that at a low velocity, a backwash might not be initiated, even if the filtration headloss is elevated. The operating value of α will be defined during the start-up phase, according to the daily flow history.

4.0 SCADA/PLC STRUCTURE

This section discusses the basic structure of the pilot control system such as:

1. Online/Offline;
2. Filter Operations (Manual and Automatic);
3. Function Modes (Filtration, Idle, Backwashes); and
4. Operation of individual equipment.

Table 3 summarizes the structure of the pilot SCADA/PLC system.

Table 3. Structure of Biostyr SCADA System

BIOSTYR SCADA SYSTEM		
ON-LINE		**OFF-LINE**
Automatic Operation (AUTO)	Manual Operation (MANUAL)	
Automatic Functions (Modes) - Filtration (Default) - Backwashes: Normal Mini	Automatic Functions (Modes) - Idle (default) - Filtration - Backwashes: Normal Mini Aggressive	Automatic Functions (Modes) - Not Available - Default position when equipment failures occur
Automatic Function Initiation: - Automatic	Automatic Function Initiation: - Manual	Automatic Function Initiation: - Not applicable.
Operation of Individual Equipment - Automatic operations are allowed for all functions - Manual operations are not allowed at SCADA screen - Manual operations at local control panel cause alarm in SCADA	Operation of Individual Equipment - Automatic operations are allowed during executions of all functions. - Manual operations at SCADA screen are allowed when functions are not running. - Manual operations at local control panel cause alarm in SCADA	Operation of Individual Equipment - No automatic operation is available. - Manual operations are allowed 1. At SCADA screen. 2. At local control panels.

4.1 OFFLINE AND ONLINE

4.1.1 Offline

As required by the structure in Table 3, there will be on-line (ON) and off-line (OFF) modes on the SCADA screen. The off-line mode is designed for performing maintenance tasks on the equipment of the pilot system; therefore, off-line is the default for the pilot system to stay when equipment failures occur (see Section 10, Failure Management).

When the pilot system is off-line, manual operations of equipment at SCADA screen through PLC and manual operation at local control panels are allowed. However, the two system operations (Auto/Manual) and their associated functions (e.g., Idle, Filtration and backwashes) are not available when the pilot system is offline.

4.1.2 Online

The following conditions must be met in order to bring the system online.

1. Power is on;
2. Instrument air pressure is high enough;
3. Pumps are in remote (AUTO) position; and
4. Automatic valves (feed valve, airflow controller, backwash flush valve) are in remote (auto) position.

While the system is online, manually switching equipment away from the remote/auto position will generate an alarm in the SCADA. Manual operation of equipment at the SCADA screen through PLC is allowed when the system is in the manual operation.

4.2 SYSTEM OPERATIONS

As shown in Table 3, after the system is brought to on-line, two different system operations are available – AUTO and SCADA manual (i.e., MANUAL). The automatic operation is designed for fully automatic operation by the PLC, whereas the manual operation is designed as semi automatic operation, that is, the operators make decision on when to launch the functions (e.g., filtration and backwashes) and PLC carries out the functions. Therefore, the PLC functions are provided to both system operations. The differences between the two system operations are:

1. In the automatic operation, PLC not only conducts the functions but also determines when to launch the functions;

2. In the manual operation, the operators determine the time to launch the functions, but the PLC carries out the functions;

3. The manual operation consists of idle, filtration and backwash functions.

4. The automatic operation does not have the idle function because the rotation among cells is not required for the pilot system that consists only one filter.

The other differences between the two system operations are in the operation of individual equipment:

1. Within the automatic operation, individual equipment is locked up by the PLC. Manual operation at the SCADA screen is not allowed. Manual operation at the local control panel will lead alarm at the PLC/SCADA system.

2. Within the manual operation, equipment is not locked. Manual operation of equipment at the SCADA screen is allowed. When conflicts between manual and automatic operations occur on a piece of equipment, the PLC will abort the automatic sequences and execute the operators' commands.

4.3 FUNCTION MODES

Functions are a batch of pre-programmed actions that will execute to the end once the functions are launched. As listed in Table 3, the manual operation consists of five functions (Function modes) – idle, filtration, and three types of backwashes, whereas the automatic operation consists of filtration and three backwashes. Brief descriptions of the listed function modes are given below:

Idle Mode. When the system is in idle mode, the system is not fed with the influent water and is aerated intermittently to keep microorganism within the media bed alive. The idle mode is primarily designed as a default, waiting mode (as defined in Section 4.2) for the manual operation. For example, when the system is switched to the manual operation, the system always is placed in the idle mode first. The system waits for the operators' commands. The idle mode also serves as a default, waiting mode when clogging failures and operators' intervention occur (For more detail see Section 10, Failure Management). It is noted for clarity that the system will be switched to off-line if equipment failures occur (For more details, see Section 10).

Filtration Mode. The water to be treated flows up through the filter bed and the nozzles. The treated water is retained in the top section of the column and flows over the effluent weir. During filtration, the system is continuously aerated. As shown in Table 3, filtration mode is available to both automatic and manual operations. In terms of operating sequence, the filtration mode in the automatic operation is the same as that in the manual operation. However, the filtration mode in the automatic operation is launched automatically, whereas the filtration mode in the manual operation is launched manually.

The filtration mode in the automatic operation is the default mode because this pilot system consists of only one unit and the constant load method for control of the number of cells in operation cannot be performed. Because filtration is the default, when the system is switched to the automatic operation, the system is always placed in the filtration mode.

Backwash Mode. Backwashes are designed to remove excess biomass and suspended solids that have accumulated in the media bed. Treated effluent is pumped back to the top section of the column from the backwash supply tank, and then flows down through the media bed by gravity and expands the media. Injection of air through the air injection pipes scours the media. The waste backwash water is discharged into the plant drain system. There are three types of backwashes – Normal, Mini, and Aggressive.

1. Normal backwash - used regularly based on time intervals or operators' decisions (i.e., launched either automatically or manually).

2. Mini backwash - used occasionally based on unusually high filtration headloss, or high percentage of clogging (i.e., launched either automatically) or operators' decisions (i.e., launched manually).

3. Aggressive backwash - used only when the normal backwash fails to restore the filtration headloss to an acceptable level and available only to the manual operation. That is, an aggressive backwash can only be launched manually.

As shown in Table 3, Normal and Mini backwashes are available to both system operations. The same name backwashes between the two system operations are the same except for launching conditions. For examples, the Normal and Mini backwashes in the automatic operation are launched automatically by SCADA whereas the Normal and Mini backwashes in the manual operation are launched manually by the operator. Once launched, the same named backwashes will follow the same sequence all the way to the end, unless interrupting conditions, such as equipment failures and operator's intervention, occur.

4.4 OPERATION OF INDIVIDUAL EQUIPMENT

As mentioned earlier, manual operation of individual equipment is allowed:

- At the SCADA screen and local control panel when the system is off-line, and
- Only at the SCADA screen when the system is on-line and in the manual operation.

Manual operation of individual equipment at SCADA screen is not allowed when the system is in the automatic operation. Manual operation of individual equipment at local control panels will lead to alarm at the control screens.

As shown in Figure 1, two control switches are available for the control of individual equipment – SCADA Control (Manual) and PLC Control (AUTO). The default position is AUTO (i.e., PLC control), which is required to run all of the automatic functions listed in Table 3, no matter what system operation the system is in. Table 4 summarizes the availability of the control switches in Figure 1 to different system operations.

Table 4. Availability of Control Switches for Individual Equipment.

ON-LINE		**OFF-LINE**
Automatic Operation (AUTO)	Manual Operation (MANUAL)	
PLC Control – Allowed SCADA Control – Not Allowed On (Open) – Not Allowed Off (Close) – Not Allowed	PLC Control – Allowed SCADA Control – Allowed On (Open) – Allowed Off (Close) – Allowed	PLC Control – Not Allowed SCADA Control – Allowed On (Open) – Allowed Off (Close) – Allowed

As shown in Table 4, only PLC control (AUTO) switch is available to the automatic operation because manual operation of individual equipment is not allowed in this mode. Both PLC control (AUTO) switch and SCADA Control (Manual) switch are available to the manual operation. This is because execution of automatic functions (filtration, idle, and backwashes) and manual operation of individual equipment both are allowed in the manual operation. When the system is off-line, the SCADA control switch is still available because manual operation of individual equipment is allowed whereas the PLC control switch is not allowed because all of automatic functions are not available.

Once the SCADA control position is selected, a switch (open/close as shown in Figure 1) is available to the operator. This switch will allow the operators to manually operate individual equipment at the SCADA screen. When the operators' commands on individual equipment operation conflict with automatic sequences required by the function modes, the PLC will abort the function modes and follow the operators' commands. Although PLC Control (AUTO) is the default position for the control switches of individual equipment, the operators need to make sure that these switches are in the AUTO position before manually launching any one of the five automatic function modes.

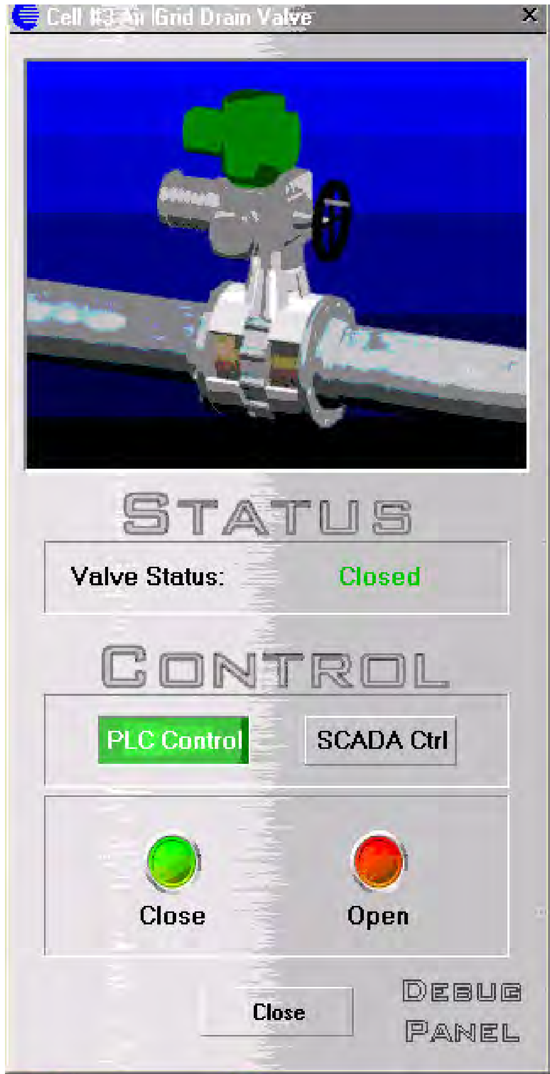


Figure 1. SCADA Inset Showing Control Switches For Individual Equipment.

5.0 IDLE MODE

The system is in idle mode, it is not fed with the influent water and is aerated intermittently to keep microorganism in the media alive. The idle mode is primarily designed as a default, waiting mode for the manual operation and is not available to the automatic operation.

5.1 INTO THE IDLE MODE

The following conditions will put the system into the idle mode in the manual operation:

1. The system, after switched to the manual operation from either the automatic operation or the off-line, will be put into the idle mode first and waits for operators' instructions. Operator's decision is needed to switch the system operation from automatic to manual or from offline to online.
2. The system in the manual operation after completing a backwash (including normal, mini and aggressive) will automatically be put in the idle mode and waits for operators' further instructions.
3. The system after interrupting from backwashes due to the operators' intervention will be put in the idle mode and waits for operators' instructions.
4. The system after filtration is interrupted either by the operator intervention and filter clogging will be put in the idle mode and waits for operators' instructions.

5.2 EXIT IDLE MODE

The system in idle mode will remain there unless one of the following conditions occurs:

1. Switch the system to the automatic operation by the operator. Once in the automatic operation, the system will default to filtration mode.
2. Switch the system to the filtration mode by the operator. This will lead the system into the filtration mode but still in the manual operation.
3. Switch the system to backwash by the operator. This will lead the system into backwash mode but still in the manual operation.
4. Switch the system off-line by the operator.
5. Exit on failures. If equipment failures occur during the idle mode, the system will be put in the offline.

6.0 FILTRATION MODE

Filtration timer t_{F_i}. The filtration timer will be defined to track the filtration time since the last normal or aggressive backwash. The timer is active when the system is in filtration mode. When the system is switched to the idle mode, the current filtration timer is stopped, but not reset. It is stopped and reset to zero at the end of a normal or aggressive backwash.

6.1 INTO FILTRATION MODE

- In manual mode, only the operator's action can launch the filtration mode.
- In automatic operation, filtration is the default mode. Every time, the system is put into the automatic operation, the system starts filtration sequence.

6.2 EXIT THE FILTRATION MODE

6.2.1 Exit the Filtration Mode In The Automatic Operation

Following Operator's Intervention: The operator can interrupt filtration in the automatic operation. After interruption, the system will be put in the idle mode of the manual operation and wait for the operators' further instruction.

Following SCADA/PLC Automatic Control:

1. By Filtration Time Since the last backwash. If the filtration time (t_{F_i}) in the automatic operation exceeds the setpoint, the system will be automatically normal-backwashed.

2. By Filtration Headloss. If the filtration headloss of the system during the automatic operation exceeds the maximum allowed (ΔP_{REF}), the system will be mini-backwashed.

3. By Percentage of Clogging. If the percentage of clogging of the system during the automatic filtration exceeds the maximum allowed (d_{REF}), the system will be mini-backwashed.

Exit On Failures:

- Equipment failure. When equipment failures occur, the system will be switched to offline in most cases (see Section 10 on Failure Management).

- Clogging failure. If the filtration headloss or percent of clogging of the system during automatic filtration is equal or greater than ΔP_{MAX} or d_{MAX}, respectively, the system will be switched to the idle mode (in the manual operation).

6.2.2 Exit The Filtration Mode In The Manual Operation

It must be noted that the system is in the manual operation does not follow the timer control as described for the filtration mode in the automatic operation. This means that the system in the manual operation will stay in filtration until one of the following conditions occur:

Operator's Intervention. Operator's intervention can interrupt the filtration mode in the manual operation. The filter after interruption will wait in the idle mode (in the manual operation) for the operators' instructions.

Exit On Failures:

- Equipment failure. When equipment failures occur, in most cases, the system will be switched to offline (see Section 10 on Failure Management)

- Clogging failure. If the filtration headloss >= ΔP_{MAX} or the Percent of Clogging >= d_{MAX}, the system will be switched to the idle mode of the manual operation.

7.0 FILTER BACKWASH

This section discusses all types of backwashes – such as backwash sequence, launching conditions, exit conditions, permissive conditions, and interrupting conditions.

The backwash sequences of operations are fully automated. Table 5 summarizes the sequences of operation of the backwashes.

Table 5 - Summary of Backwash Sequences and Time Durations

	Normal Backwash	Mini backwash	Aggressive backwash
Volume of Water	$3.5V_{bed}$	$1.75V_{bed}$	$3.5V_{bed}$
Initial Water Rinse			
Rinse Velocity, Nm/h (gpm/ft^2)	60-70 (24-28)	60-70 (24-28)	25-35 (10-14)
Duration, Sec.	15-60	15-60	15-60
Initial Air Scour			
Scour Velocity, Nm/h (scfm/ft^2)	12-20 (0.65-1.1)	12-20 (0.65-1.1)	12-20 (0.65-1.1)
Duration, Sec.	30-120	30-120	30-120
Pause			
Duration, Sec.	0-300	0-300	0-300
Middle Phases			
Number of Cycles, times	2 or 3	NA	2 or 3
Water Rinse			
Rinse Velocity, Nm/h (gpm/ft^2)	60-70 (24-28)	NA	60-70 (24-28)
Duration, Sec.	30-180	NA	30-180
Air Scour			
Scour Velocity, Nm/h (scfm/ft^2)	12-20 (0.65-1.1)	NA	NA
Duration, Sec.	30-120	NA	NA
Simultaneous Air and Water			
Rinse Velocity, Nm/h (gpm/ft^2)	N/A	NA	25-35 (10-14)
Scour Velocity, Nm/h (scfm/ft^2)	N/A	NA	5 (0.27)
Duration, Sec.	N/A	NA	30-180
Pause			
Duration, Sec.	0-300	NA	0-300
Final Rinse			
Rinse Velocity, Nm/h (gpm/ft^2)	60-70 (24-28)	60-70 (24-28)	60-70 (24-28)
Duration, Sec.	120-360	120-360	120-360

7.1 LAUNCHING CONDITIONS

The sequences are generally triggered by one of the following conditions:

1. Pre-set time limit (filtration time) has expired;
2. When the headloss across the filter or percentage of clogging exceeds a pre-set limit;
3. The operator' s decision.

As mentioned earlier in Table 3, two types of backwashes, mini and normal backwashes, are executed from automatic operation. The normal backwash is an integral part of normal operation of Biostyr. The system filtration timer reaching the backwash setpoint triggers it.

The mini backwash is launched when the filtration headloss or the percent of clogging is higher than the allowable (ΔP_{REF} or d_{REF}, respectively). The mini backwash partially cleans the media, allowing the filter to continue filtration until the next normal backwash.

Aggressive backwash is not provided in the automatic operation because automatic launching of aggressive backwash is not allowed.

All three types of backwashes are also provided in the manual operation. The operator can launch any backwashes in manual operation.

Although it is operator's decision to launch an aggressive backwash, an aggressive backwash is recommended under the following conditions:

1. The filtration headloss ($\Delta P(t)$) is higher than the maximum headloss setpoint (ΔP_{Max});
2. The percent of clogging is higher than the maximum percentage of clogging setpoint (d_{MAX}).

3. Two consecutive mini backwashes are requested within a short period of time.

Meeting one of the above three conditions does not incur a manual normal backwash automatically. The SCADA/PLC gives off an alarm for the operators' attention. The operators can launch an aggressive backwash without meeting the above three conditions.

7.2 EXIT CONDITIONS

1. Completion of normal backwash. After completion of the normal backwash, the system in the manual operation exits to the idle mode in the same system operation. If the system is in automatic operation, it exits the backwash mode into filtration mode.

2. Completion of mini backwashes. After completion of a mini backwash, the system in the manual operation exits to the idle mode in the manual operation. The system in the automatic operation exits to the filtration mode in the automatic operation.

3. Completion of aggressive backwashes. After completion of an aggressive backwash, the system exits to the idle mode in the manual operation.

7.3 PERMISSIVE CONDITIONS

Unless specified, the permissive conditions discussed below apply to all backwashes. A backwash is not permitted if one of the following conditions is true:

- A high level switch in the backwash supply tank is not reached.

- Any equipment is not in the remote/automatic mode.

- A backwash is currently in progress.

7.4 INTERRUPTING CONDITIONS

A backwash (all types) in progress will be interrupted to the manual idle mode if the following conditions are experienced.

1. Low water level switch in backwash supply tank is reached;
2. Operator's decision – "terminate backwash" button in the SCADA system;
3. Equipment failures (e.g., valve failures or instrument air system failure).

The above conditions apply to all types of backwashes. If one condition occurs, the following actions will be taken to interrupt a backwash:

1. The backwash valve is closed (the backwash in progress is terminated);
2. An alarm is given; and
3. When the alarm is acknowledged, the filter is transferred into idle mode in the manual operation.

Whatever the status of the backwash before the interruption, the backwash is considered incomplete.

8.0 CONTROL OF AIRFLOW RATE

This section will discuss airflow rate control during filtration, backwash, and idle.

8.1 AERATION SYSTEM EQUIPMENT

The system requires process air during filtration and scour air during backwash. Air is supplied by an air compressed system. Air flow for both process and backwash demands is controlled by the airflow control valve/flow meter (Alicat). This device provides both mass flow measurement and flow control.

8.2 AIRFLOW CONTROL IN FILTRATION MODE

Airflow regulation during filtration is conducted one of two ways:

- Generating an airflow setpoint based on the effluent DO measurement, or
- A constant airflow rate entered via a SCADA setpoint.

8.2.1 Generating Setpoint Based on DO

The dissolved oxygen (DO) sensor is located in the top of the column, above the nozzle deck. As shown in Figure 2, the Kruger SCADA system allows the operator to select a DO setpoint. The setpoint will be chosen based on the operator's treatment objectives. The DO controller will produce or increment the process airflow setpoint based on the effluent DO measurements. The process airflow setpoint is directed to the Alicat flow controller via a 4-20mA signal. The Alicat will adjust to the flow setpoint using its own internal PID control loop and proportional control valve.

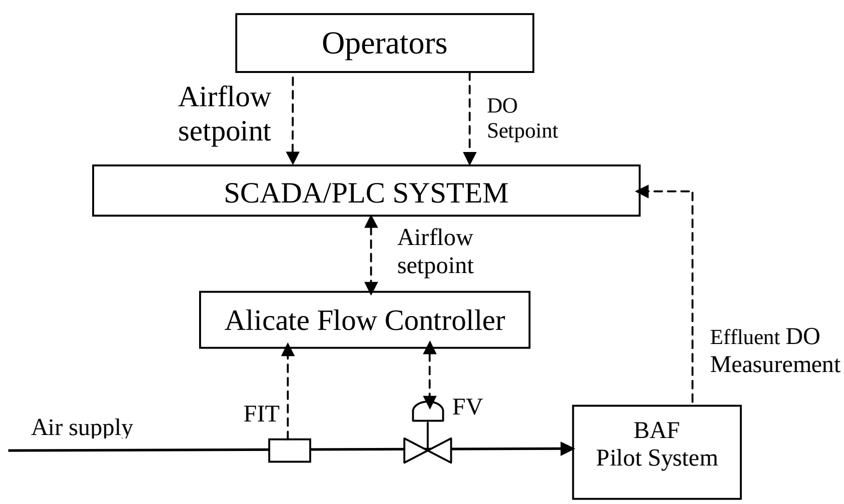


Figure 2. Block Diagram of Pilot System Process Air Control

- The airflow setpoint shall be adjusted in increments of 0.05 scfm. (This proposed value assumes that resolution is within the capability of the flow meter and valve combination. If it is not, use the lowest value that will give stable response.)

- The deadband on the DO measurement shall be ± 0.2 mg/L. No change to the airflow setpoint will be made while the effluent DO is within this range.

8.2.2 Constant Air Flow Rate

As shown in Figure 2, the SCADA system shall provide an option to run air at a constant mass flow rate (scfm). The operator shall enter the rate as a SCADA setpoint. The airflow control valve will modulate to maintain the flow setpoint. The setpoint range shall be 0.0 - 3.0 scfm.

8.3 AIRFLOW RATE CONTROL IN IDLE MODE

Intermittent aeration is provided during idle mode to keep the biomass alive. The air-on and air-off periods of the intermittent aeration cycle are entered as SCADA setpoints. The target airflow for the air-on period is in the range of 0.27-0.85 scfm/ft^2. Therefore, the airflow setpoint range is 1.0 to 3.0 scfm**.**

8.4 AIRFLOW RATE CONTROL IN BACKWASH MODE

For all backwashes, air is needed for scouring the media. The airflow setpoints are 0.85 scfm/ft^2 for the air-only scouring phase and 0.27 scfm/ft^2 for simultaneous air-and-water phases of an aggressive backwash.

The airflow to the pilot system during a backwash stops and starts repeatedly in relatively short time (typical scour duration is only 60 seconds). Therefore, the modulating air valve will need to provide quick response to meeting the airflow setpoint.

9.0 MIXER AND PUMP CONTROL

9.1 BACKWASH SUPPLY TANK MIXER

The backwash supply tank mixer shall be controlled by the PLC. The mixer is equipped with constant speed motor. There is no PLC control loop for mixer control. The mode of operation is always manual. However, the SCADA/PLC system will include equipment interfaces to start and stop the mixer.

9.2 FEED PUMP

The feed pump is a variable speed, positive displacement pump. Operating modes are manual and automatic. An HOA switch and speed control dial are also provided on the Biostyr control panel for manual operation.

In automatic mode, the pump will maintain the feed flow setpoint - Q_{column} - specified by the operator in the SCADA setpoints. The following exceptions are noted:

- In pump automatic mode, the pump stops during backwash
- In pump automatic mode, the pump stops under various failure scenarios, defined in Section 10.

In pump manual mode, the operator may start or stop the pump and specify the speed of operation: 0-100% range.

The flow setpoint for the pump – Q_{column} – is a single value. However, the SCADA system shall provide two flow mode options:

- Constant flow
- Diurnal flow

In diurnal mode, flow is adjusted according to a table of setpoint multipliers provided in the SCADA system. The table will have 24 values, one corresponding to each hour of the day. The flow target during a given hour is calculated as follows:

$$Q_{target} = Q_{column} \text{ x } m_i$$

where m_i is the multiplier for hour i. The range of m_i shall be 0.0-5.0.

9.3 CONTROL OF BACKWASH SUPPLY PUMP

The backwash supply tank is equipped with one constant-speed pump to supply water to the top of the column during the rinse phase of a backwash. The top section of the column is equipped with low and high level switches. The low level switch turns the supply pump on during a backwash. The high level turns it off.

10.0 FAILURE MANAGEMENT

The purpose of failure management is to protect the pilot system from:

1. Loss of media
2. Overflow
3. Equipment damage

10.1 FAILURES OF THE PILOT SYSTEM

There are two types of failures for a Biostyr operation - equipment and clogging. Table 6 summarizes default positions of the automatic valves when a failure occurs to them.

Table 6. Default Valve Positions When An Equipment Failure Occurs.

Equipment	Status
Inlet valve (ZSC & ZSO)	Closed
Air flow controller (ZT)	Closed
Backwash flush valve (ZSC & ZSO)	Closed

Equipment Failure. Equipment failures are caused by faults with control equipment and instrument. When an equipment failure occurs to the pilot system, an alarm will be given by the PLC. In most cases – see below – failure of individual equipment will lead to a failure of the system; i.e., the system will be switched to offline.

Clogging Failure. When one of the following conditions is true, the system is experiencing a clogging failure:

1. Maximum filtration headloss limit is reached ($\Delta P >= \Delta p_{max}$) for a period of time;
2. Maximum percent of clogging limit is reached (d_{MAX}) for a period of time;
3. Two (2) mini backwashes are requested within a period of time.

When one of the above conditions occurs, the control system will give off an alarm for the operators' attention. The system will be put into the idle mode of the manual operation and wait for the operators' instructions.

10.2 LOSS OF POWER

In this situation, the pilot system will be stopped.

10.3 FAILURE ON INDIVIDUAL INSTRUMENT AND EQUIPMENT

This section will discuss actions/measures that will be taken when individual equipment fails.

10.3.1 Feed Valve

When a fault is detected on the feed valve, the system is transferred into the off-line mode. An alarm is sent for operator's attention. When the failure is acknowledged and solved, the system can be brought back on-line.

10.3.2 Mass Airflow Controller (Valve and Meter)

When a failure appears on the airflow controller, the system is transferred into the off-line mode. An alarm is sent for operator's attention. When the failure is acknowledged and solved, the system can be brought back on-line.

10.3.3 Backwash Valve

When the backwash valve fails to open during a backwash, the backwash is stopped and the system is transferred into the off-line mode. An alarm is sent to the operators. When the failure is acknowledged and solved, the system can be brought back on-line.

10.3.4 System Pressure Transmitter

When a failure appears on the pressure transmitter located at the bottom of the system, the headloss across the media bed is not known by the PLC, the system must be transferred to the off-line. When the failure is acknowledged and solved, the system can be brought back on-line.

10.3.5 Influent Flow Meter

When there is a failure on the influent flow meter, an alarm is generated. The Biostyr system is transferred to the off-line.

10.3.6 Backwash Flow Meter

When there is a failure on the waste backwash flow meter, an alarm is generated for the operators' attention. The system keeps running, and the operators decide actions.

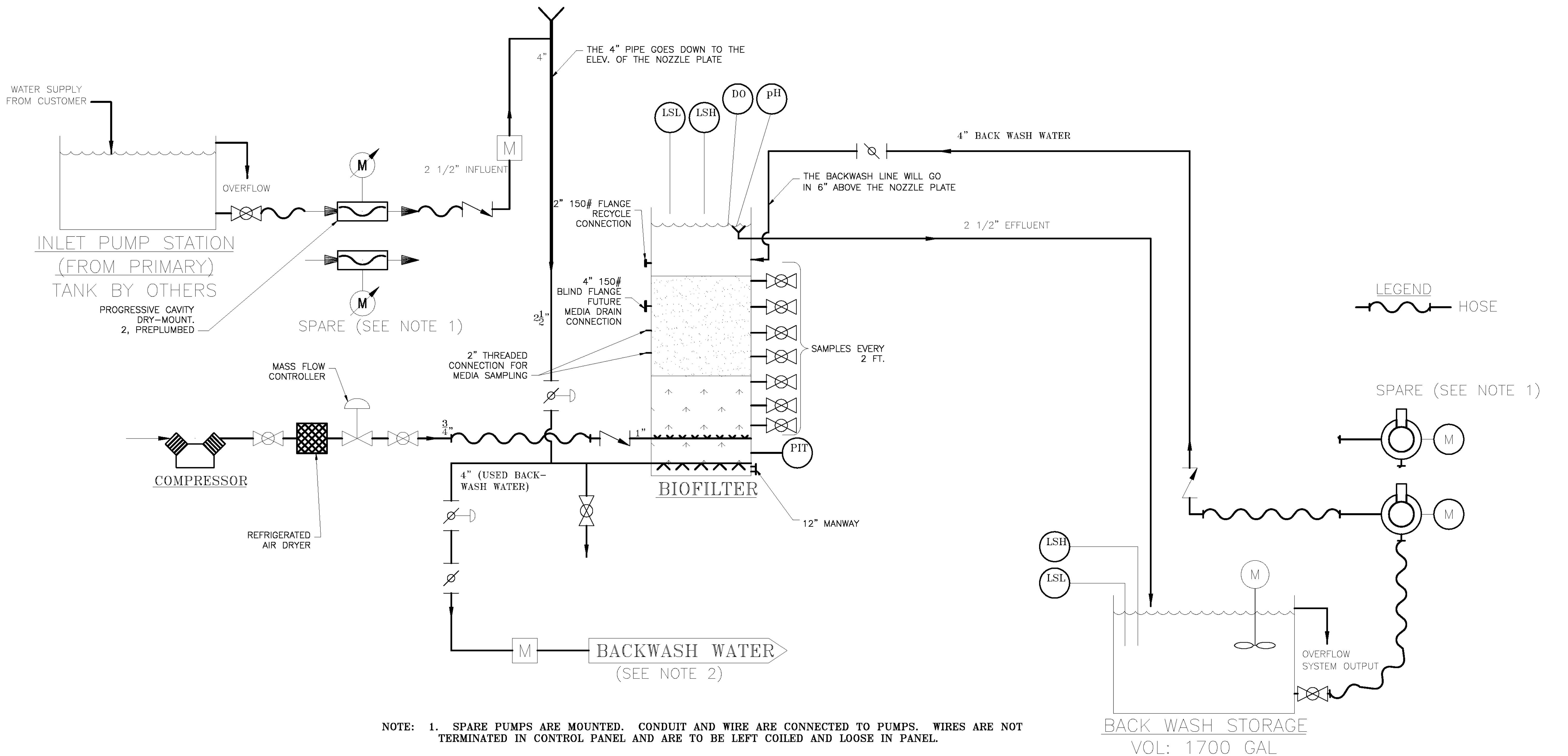
10.3.7 Effluent DO Probe

When there is a failure of the effluent DO probe, the air flow control defaults to constant flow mode. An alarm is generated. The system keeps running.

10.3.8 Effluent pH Probe

When there is a failure of the effluent pH probe, an alarm is generated for the operator's attention. No other action is necessary.

APPENDIX A - PROCESS & INSTRUMENTATION DIAGRAMS



NOTE: 1. SPARE PUMPS ARE MOUNTED. CONDUIT AND WIRE ARE CONNECTED TO PUMPS. WIRES ARE NOT TERMINATED IN CONTROL PANEL AND ARE TO BE LEFT COILED AND LOOSE IN PANEL.

2. ELEV. OF BACKWASH DISCHARGE MUST BE 1'-0" HIGHER THAN AIR GRID.

THE PRESENCE OF A PROFESSIONAL ENGINEERS SEAL ON THIS DRAWING INDICATES THAT A SIGNED AND SEALED ORIGINAL IS ON FILE.

rev	date	description	dwn	chk	appv
1	12.15.03	UPDATED	SPR	.	GAT
0	09-02-03	PRELIMINARY RELEASE	DSD	.	SDD

GRAPHICAL SCALE 0 0.5 1 2 3 6

DESIGNER DSD	DATE 09.02.03	TITLE PROCESS FLOW DIAGRAM BIOSTYR PILOT UNIT
CHECKER .	DATE .	CLIENT PT. IOMA, CA
ENGINEER SDD	DATE .	USFilter KRUGER PRODUCTS 401 HARRISON OAKS BLVD CARY, NC 27513 (919) 677-8310 FAX (919) 677-0082
MANAGER .	DATE .	
FILE: .		
SCALE: NTS		

CLASSIFICATION	PROJECT No.	DRAWING	SHEET	REV
.	42809812	385PFD01	1 OF 1	1

INTERNAL REF NO:

IF BAR IS NOT 1", ADJUST SCALE ACCORDINGLY