Volume 2 : Edition 7 – Ultra Filtration Design & BOQ Generation Jul 31, 2022

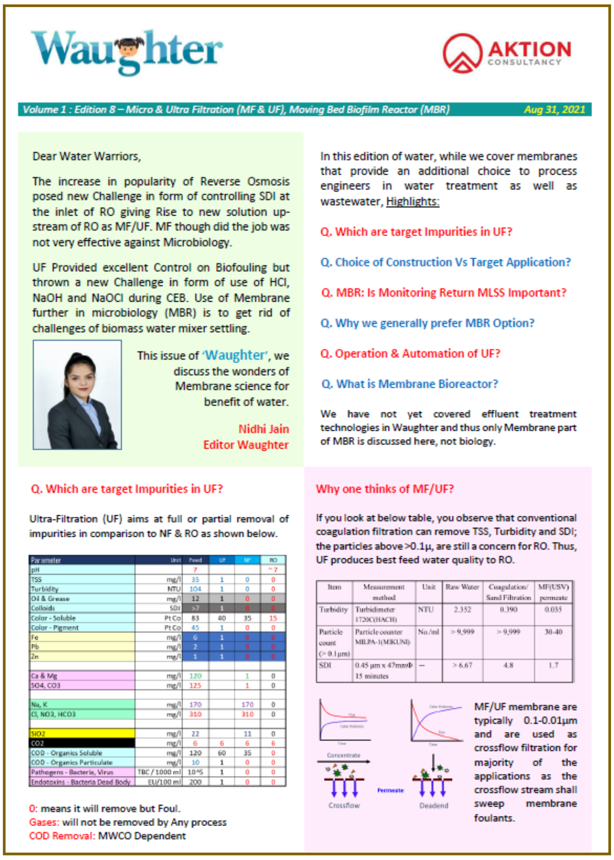
Dear Water Warriors,

With Reverse Osmosis systems offering challenges due to frequent fouling – biological, particulates or colloids, designers started paying attention to SDI control in pre-treatment and UF provided an Automatic Choice.

With time, in-order to optimize UF cost, designers started to employ backwash sequences with Acid, Alkali etc to have higher flux.

This issue of '**Waughter**', we present the steps to design a UF system and understand important Material involved in designing UF System.

Nidhi Jain – Civil Engineer



Volume 1 : Edition 8 – Micro & Ultra Filtration (MF & UF), Moving Bed Biofilm Reactor (MBR) Aug 31, 2021

Dear Water Warriors,

The increase in popularity of Reverse Osmosis posed new Challenge in form of controlling SDI at the inlet of RO giving Rise to new solution up-stream of RO as MF/UF. MF though did the job was not very effective against Microbiology.

UF Provided excellent Control on Biofouling but thrown a new Challenge in form of use of HCl, NaOH and NaOCl during CEB. Use of Membrane further in microbiology (MBR) is to get rid of challenges of biomass water mixer settling.

This issue of 'Waughter', we discuss the wonders of Membrane science for benefit of water.

Nidhi Jain
Editor Waughter

In this edition of water, while we cover membranes that provide an additional choice to process engineers in water treatment as well as wastewater, Highlights:

Q. Which are target Impurities in UF?

Q. Choice of Construction Vs Target Application?

Q. MBR: Is Monitoring Return MLSS Important?

Q. Why we generally prefer MBR Option?

Q. Operation & Automation of UF?

Q. What is Membrane Bioreactor?

We have not yet covered effluent treatment technologies in Waughter and thus only Membrane part of MBR is discussed here, not biology.

Q. Which are target Impurities in UF?

Ultra-Filtration (UF) aims at full or partial removal of impurities in comparison to NF & RO as shown below.

Parameter	Unit	Feed	UF	NF	RO
pH		7			~7
TSS	mg/l	35	1	0	0
Turbidity	NTU	104	1	0	0
Oil & Grease	mg/l	12	1	0	0
Colloids	SDI	>7	1	0	0
Color - Soluble	Pt Co	83	40	35	15
Color - Pigment	Pt Co	45	1	0	0
Fe	mg/l	6	1	0	0
Pb	mg/l	2	1	0	0
Zn	mg/l	1	1	0	0
Ca & Mg	mg/l	120		1	0
SO4, CO3	mg/l	125		1	0
Na, K	mg/l	170		170	0
Cl, NO3, HCO3	mg/l	310		310	0
SIO2	mg/l	22		11	0
CO2	mg/l	6	6	6	6
COD - Organics Soluble	mg/l	120	60	35	0
COD - Organics Particulate	mg/l	10	1	0	0
Pathogens - Bacteria, Virus	TBC / 1000 ml	10^5	1	0	0
Endotoxins - Bacteria Dead Body	EU/100 ml	200	1	0	0

0: means it will remove but Foul.
Gases: will not be removed by Any process
COD Removal: MWCO Dependent

Why one thinks of MF/UF?

If you look at below table, you observe that conventional coagulation filtration can remove TSS, Turbidity and SDI; the particles above >0.1µ, are still a concern for RO. Thus, UF produces best feed water quality to RO.

Item	Measurement method	Unit	Raw Water	Coagulation/ Sand Filtration	MF(USV) permeate
Turbidity	Turbidimeter 1720C(HACH)	NTU	2.352	0.390	0.035
Particle count (> 0.1 µm)	Particle counter MILPA-1(MIKUNI)	No./ml	> 9,999	> 9,999	30-40
SDI	0.45 µm x 47mmΦ 15 minutes	—	> 6.67	4.8	1.7

Concentrate
Permeate
Crossflow
Deadend

MF/UF membrane are typically 0.1-0.01µm and are used as crossflow filtration for majority of the applications as the crossflow stream shall sweep membrane foulants.

Waughter Vol 1 Edi 8 … ReCap

In above publication we have already discussed about the use of Ultra-Filtration with key words like

- Cross Flow Vs Dead End
- Target UF Impurities: Particulates, Bacteria Virus
- Hydrophilicity
- Choice of Membrane Material
- Operation & Control Philosophy
- Role of Backwash & CEB

Waughter Readers, please download above from www.aktioconsultancy.com and move further for designing a UF system.

Also please download the Software UF design in XLS and if any difficulty please write to us to provide the software to you.

Design of UF System… defining application!

A Customer has given the problem as hereunder:

We need 55 m^3/h, UF Plant for treated Sewage application. Currently we have RO Plant of capacity 45 m^3/h and that is not performing well and chocking often. The idea of UF is to protect RO membranes. The treated sewage data is:

TSS	mg/l	:	85
COD	mg/l	:	110
BOD	mg/l	:	29
pH		:	7.5

The system need to be accommodate in the space of 3 * 3 m available in the RO Plant.

Now let's understand this requirement.

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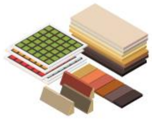

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The Role of RFQ Format

UF is a cyclic automated process. Further most of the time UF is not a standalone technology. It has:

A. An Upstream process such as STP or ETP or simple Reservoirs and Intake in case of River water.

B. A downstream process e.g. RO or IX based DM Plant

Further, irrespective of Upstream or Downstream operational SOPs, the UF operation is always 100% automatic based on PLC.

Further like any technology, we have a limit of impurities set by different membrane manufacturers.

The designer shall pay attention to the limiting conditions as specified by the membrane manufacturer.

The UF feed water Limits

Below are the limiting conditions defined by a membrane manufacturing company:

Turbidity, NTU	300
TSS, mg/l	50

The above define % Cross flow to be maintained as these impurities do not pass UF capillary and accumulate in housing. The cross flow is 10%, unless these limits in feed water are < 25% of maximum limits.

pH Max	10.5
COD mg/l	250
Temperature °C	40
Oil & Grease, mg/l	50
FRC, mg/l	1

These values are defined considering UF material, Housing material & Potting Resin used in manufacturing a UF Module.

General Information	
Date	
Customer Name	
Address	
Contact Person	
Contact No.	
Industry Type	Power/Textile/Pharma/Chemical/Other -
Plant Details	
Name of OEM (WTC)	
Expected Purchase Date	
Plant Capacity, m3/d	
No. of Streams	
Water Source	Please Check Engineering Process Fact Sheet
Specify Media Filter Need	Yes / No
Key Water Analysis	

Turbidity	TSS	TDS	Total Alkalinity	Calcium Hardness	Total Hardness	Color	COD	Temp	pH
NTU	mg/l	mg/l	mg/l	mg/l $CaCO_3$	mg/l		mg/l	°C	

Any Specific Request:

Attach Water Analysis Report if Applicable:

What shall be use of UF Product:

Urgency for Quote: ______ days

Name

The Specifications from Client are very important and must be structured in the RFQ as shown:

Its important to know the type of Industry as Sewage may get some contamination based on the Industry Type.

UF is a batch process and that too in Auto-operation mode so one must check.

- Storage before UF
- Storage After UF

Further TDS decides the metallurgy of Pumps involved. Alkalinity, temperature and Hardness Define the LSI of feed water and thus the need of pH Correction in UF Feed tank to avoid scaling on UF membranes.

If LSI is < -0.3, you need not do CEB with hazardous chemicals such as HCl.

Finally, UF generates the treated water for it's own backwash. So, it's always must to define nett flow in m3/day for designing a UF system. (1320 m3/d)

Waughter

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Volume 2 : Edition 7 – Ultra Filtration Design & BOQ Generation Jul 31, 2022

Flux Guidelines?

The better the feed water higher is the flux. And for very bad water fed in UF the flux needs to be reduced.

Since the backwash water is clean UF Filtered water the flux during backwash is constant, irrespective of the feed water. The guideline that our designers can safely follow are given below:

Operating Flux Guidelines for Type of Water	Unit	Flux			Back Wash
		Dead - End	Cross-Flow		
			With Filter	Without Filter	
Bore Water	$l.m^{-2}.h^{-1}$	80			**160**
Surface Water	$l.m^{-2}.h^{-1}$	50	100	70	**160**
Treated Sewage	$l.m^{-2}.h^{-1}$		80	50	**160**
Treated Effluent	$l.m^{-2}.h^{-1}$		60	40	**160**
Effluent with Solvent*	$l.m^{-2}.h^{-1}$		50	40	**160**
Sea Water	$l.m^{-2}.h^{-1}$		50	30	**160**

Step 1

Flux. So, we need to select flux for our case. From above table it can be 50 – 80 lmh and that decision rests on availability of filter post STP. Let's consider a Filter and select the operating flux as 80 lmh.

Step 2

UF Feed Water Tank. We need to now place PSF after STP and then have a Filtered water storage Tank to feed to UF. Since operation cycle of UF and PSF are different the capacity of UF feed tank shall be such that the UF operation is not interrupted during PSF Backwash ~ 1 Hr Feed storage.

Step 3

UF Feed Pump. Simple it shall be sized for xx m3/h @ 30 mwC. The Shut off pressure of this pump shall be < maximum allowable feed pressure for UF membranes. The capacity XX shall be arrived at later after mass balance.

Remember it's Cross flow operation so the extra water rejected by UF membrane need to go back to STP inlet and shall come back through STP and PSF back as feed.

(72 m^3/h) after Final Design.

Step 4

UF protection from unwanted material. Install a Metallic or AEP strainer of size 100 – 200 microns. Some engineers offer unwanted logic that we have PSF before so PSF will any way give ~ 35-micron quality so why we should have a strainer?

Strainers are given before UF to avoid any accidental ingress of sand carbon or any debris that may come in UF feed tank. It's a must. Plan for auto flushing of this strainer and for large plant keep a DPI for this strainer as well.

Step 5

Select Membrane. Unlike RO membranes, the manufacturers are yet to agree to a standardized size and we have no of different UF modules based on Filtration Surface Area of UF fibre. See below:

Physical PROPERTIES					
Configuration	-	Cross-flow/ Dead end			
Membrane Type	-	Hollow Fibers			
Membrane Material	-	PolyNorbit	PolyNorbit	PolyNorbit	PolyNorbit
Housing Material	-	UPVC			
Nominal Membrane Area	m2	9	26	37	55
Fiber Dimensions	OD | ID mm	1.2 & 0.8			
Pore Size	micron	0.02			
Diameter	mm [inch]	90 [3.54]	160[6.29]	200 [7.87]	200 [7.87]
Length	mm [inch]	1130 [44]	1130 [44]	1280 [50]	1792 [70]
Weight	kg (ave)	7	18	28	39
MWCO (Nominal)	kDa	75			
System Integration	-	Modular Rack			

For above specification since we have flow rate as 55 m^3/h and we have selected flux as 80 $l/m^2.h$, the membrane Area required for our design is:

Membrane Area = Flow ÷ Flux
= 55000 lph ÷ 80 $l/m^2.h$
= 688 m^2

If we select the membrane with 55 m3 area, the no of membranes required would be = 688 ÷ 55 = 12.5

So, our design shall have 13 Nos of membrane with 715 m^2 total surface.

Step 6

Backwash Pump Selection. In previous step we understand 715 m2 surface is required for keeping Flux guideline under check. If the backwash flux is 160 lmh the flow rate for backwash shall be:

= 715 * 160 = 114400 lph
~ 115 m^3/h

Further if we consider 29 min operation and 1 min backwash time, we have 1 cycle of 30 mins. Means 48 such cycles in a day. So water wasted in backwash is

= 48 * (115 ÷ 30) = 92 m3

Water Produced per day = (55*29 ÷ 60) * 48 = 1298 m3

So we lose ~ 7.21 % water during backwash and that much would have to be fed extra and the no of membranes shall be revised accordingly.

Step 7

Use XLS. Based on the data fed in membrane design XLS now the revised specifications would be:

Description	Unit	Value
Nos Needed	Nos	15.00
Back Wash Pump Needed	m3/h	123
Feed Flow	m3/h	65
Feed Flow with cross Flow	m3/h	72
Recovery without CF count		91
Recovery with CF count		87
Gross Production	m3/d	1419
Nett Production	m3/d	1320
Cycle Time	min	30
No of Cycles/day	Nos	48
BW Duration	min	1
FF Duration	min	1

Since the impurities in feed water in our design case are higher than usual on maximum allowable limits, we added a step of "Forward Flush".

Step 8

Once the Design is done, we go towards enlisting the equipment needed for complete skid.

Sr No	Parameter	Unit	Value
1	Feed Flow	$m^3.h^{-1}$	65
2	Cross Flow	$m^3.h^{-1}$	7
3	Feed Flow with Cross Flow	$m^3.h^{-1}$	72
4	Permeate Flow (nett)	$m^3.h^{-1}$	55
5	BW In Flow	$m^3.h^{-1}$	123
6	BW Out Flow	$m^3.h^{-1}$	123
7	Filtration Flux	$l.m^{-2}.h^{-1}$	80
8	B/W Flux	$l.m^{-2}.h^{-1}$	160
9	CIP In flow	$m^3.h^{-1}$	65
10	Membrane Type	-	GRAFil 8060
11	Membrane Nos	Nos	15
12	Port Connection Size	mm	50
13	CIP Tank Size - Calculated	l	988
14	CIP Tank Size Provided	l	2000

Step 9

Next step is to go for valve size and Pipe Size. We also need to understand which valves are auto operation and which ones are manual.

Sr No	Valve ID	Tag	Calculated NB	Selected NB	Qty	Type of Valve
1	Feed Effluent	V1	113	125	1	Auto
2	Permeate	V2	107	125	1	Auto
3	BW In	V3	148	150	1	Auto
4	BW Out	V4	148	150	1	Auto
5	Cross Flow Out	V6	36	40	1	Manual
6	Drain	V5	113	125	1	Manual
7	CIP Chem In	V7	107	125	1	Manual
8	CIP Chem Out	V8	107	125	1	Manual
9	Module Isolation	IsoVs	NA	50	30	Manual

a. Valve shall be sized for 2.0 m/s velocity.
b. Auto Valve can be with Pneumatic or electrical actuators.
c. Bottom line: Always Auto operation.

Volume 2 : Edition 7 – Ultra Filtration Design & BOQ Generation Jul 31, 2022

Role of CEB and how to design it?

Chemical Enhanced Backwash is extension of membrane cleaning procedure to avoid high TMP. In our case we have 48 cycles of backwash. We can

a. Inject 500 mg/l dose of Citric Acid @ 10% Solution during backwash. (Scale Cleaning)
b. Inject 500 – 1000 mg/l dose of NaOCl @ 10% Solution during backwash. (Bio Fouling Control)
c. Inject 500 mg/l dose of NaOH @ 30% Solution during backwash. (COD & Organics, O&G Cleaning)

The Capacity of Pumps & Tanks Required for CEB shall be as below.

Chemical		Citric Acid	NaOCl	NaOH
Application Flow	m^3/h	125	125	125
Dose	mg/l	500.00	1000.00	500.00
Applied Conc	%	10	10	30
Liquid Dosing Required	lph	625.0	1250.0	208.3
Selected Pump	lph	750	1500	250
Applied Frequency Per day		4	2	2
Solution Preperation Frequency	h	24	24	24
Storage tank Volume	lpd	3000	3000	500

Final BOQ with Instruments?

UF are usually skid Mounted plants. For larger plant > 3 membranes, it's recommended to install the pumps separately on foundations.

Sr No	Type	Item	Tag No.	MOC	Unit	Size/ Capacity	Quantity
1	Mechanical	Feed Tank		HDPE	m3	60	1
2	Mechanical	Product Tank		HDPE	m3	60	1
3	Mechanical	CIP Tank	Tank	HDPE	l	2000	1
4	Module	GRAFiL 8060 Module	UF	UF Membrane	m2	55 m2	15
5	Electro Mech	Feed Water Pump	P1	SS 316		72 m3/h @ 3 Kg/Cm2	1
6	Electro Mech	Suction Valve		UPVC-M		150 NB, Ball Valve	1
7	Electro Mech	Discharge Valve		UPVC-M	mm	125 NB, Ball Valve	1
8	Electro Mech	Discharge Valve - NRV		UPVC-M	mm	125 NB, NRV	1
9	Electro Mech	Backwash Water Pump	P2	SS 316		125 m3/h @ 2.0 Kg/Cm2	1
10	Electro Mech	Suction Valve		UPVC-M		200 NB, Ball Valve	1
11	Electro Mech	Discharge Valve		UPVC-M	mm	150 NB, Ball Valve	1
12	Electro Mech	Discharge Valve - NRV		UPVC-M	mm	150 NB, NRV	1
13	Electro Mech	CIP Pump	P3	SS 316		72 m3/h @ 3 Kg/Cm2	1
14	Electro Mech	Suction Valve		UPVC-M		150 NB, Ball Valve	1
15	Electro Mech	Discharge Valve		UPVC-M	mm	125 NB, Ball Valve	1
16	Electro Mech	Discharge Valve - NRV		UPVC-M	mm	125 NB, NRV	1
17	Electrical	Motor Feed Pump			KW	From Vendor	
18	Electrical	Motor BackWash Pump			KW	From Vendor	
19	Electrical	Motor CIP Pump			KW	From Vendor	
20	I/C Valves	Feed Valve	V1	Auto Ball Valve	mm	125	1
21	I/C Valves	Permeate valve	V2	Auto Ball Valve	mm	125	1
22	I/C Valves	Backwash In Valve	V3	Auto Ball Valve	mm	150	1
23	I/C Valves	BW Out Valve	V4	Auto Ball Valve	mm	150	1
24	I/C Valves	Drain Valve	V5	Manual Ball Valv	mm	40	1
25	I/C Valves	Cross Flow Valve	V6	Manual Ball Valv	mm	125	1
26	I/C Valves	CIP In Valve	V7	Manual Ball Valv	mm	125	1
27	I/C Valves	CIP Out Valve	V8	Manual Ball Valv	mm	125	1
28	I/C Valves	Manual Isolation valve	IV 1, IV 2	Manual Ball Valv	mm	50	4
29	Instrument	Pressure Gauge		SS Boudon			5
30	Instrument	PG Isolation Valve		SS Bourdon			5
31	Instrument	Pressure Transmitter	PT				2
32	Instrument	Flow Transmitter	FT / FI				2
33	Instrument	Control Panel - PLC					1
34	I/C Pipework			Lot			1
35	Skids			Lot			1

We need support of Instruments to facilitate auto operation of the plant. For this project we have recommended for PTs as well as FTs in the Design. PLC would be able to get these 4-20 Amps data in its memory and can calculate:

- Flux
- Trans Membrane Pressure Differential
- Permeability

  Flux/TMP so that we can take a call when to do CIP or if change in frequency of CEB is recommended.

The Final Points

- Chemical Enhanced Backwash is applied only, if necessary, based on Quality of Feed. Use of chemicals daily reduces plant life.
- Air Injection while helps in cleaning can lead to severe Bio-fouling. Please be aware.
- CIP shall be performed minimum once in 3 months even if everything is in order.
- Operation & Maintenance Manual are just guideline in details. Simple operating SOPs and Work Instructions WI shall be developed based on Operation Teams Skills and Understanding.

Volume 2 : Edition 7 – Ultra Filtration Design & BOQ Generation Jul 31, 2022

Campus Update?

We wished to include fresher engineers in Aktion Indiaa.

Aparna, Anuradha, Sonali, Vaishnavi, Deepa, Antora & Vrushika now support our customers. We grow in delivery and numbers.

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It's Worth it!!

My first Offline Training Program that to with the fresh engineers of 2022 batch. Anxious, curious and half done due to 4 semester lost in Covid-19 pandemic.

on this day I remember the hardship the budding engineers have faced during lockdown - no college, Online exams, no colleagues to discuss.

All well that ends well!! #training #engineers #civilengineers #mechanicalengineers #electricalengineers #instrumentationandcontrol #freshershiring #get #campus #covid #onl #inestudy

Thank you Sanjeev Srivastava and Ashwini vernekar.

You and 104 others 4 comments

Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead.

Our next edition focuses on: "STP Design for Indian Conditions of Tendering"

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