AKUALYS AGM/ASM HANDBOOK

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1. INTRODUCTION

Ultra-filtration (UF) is a kind of membrane filtration. Process principle of UF can be described as that hydrostatic pressure forces a liquid against a semi-permeable membrane. Suspended solids and solutes of high molecular weight are retained, while water and low molecular weight solutes pass through the membrane. Particles, colloids, dissolved molecules and biological contaminants from fluids under a feed pressure are separated by UF process. On the other hand, nano-filtration (NF) and reverse osmosis (RO) systems have been used to purify tap water to distilled water quality in which salts and small molecules are separated from low molecular weight solutes. Among these methods, UF is the most frequently used for waste-water treatment owing to the fact that it can be controlled and maintained easily and cost of it is relatively lower than NF and RO systems.

UF membranes removes particles colloids, proteins, macro-molecules, bacteria and viruses from a feed solution. Schematic illustration of membrane filtration spectrum is shown in Figure 1. The molecular weight cut-off (MWCO) value is a minimum molecular weight of a solute to obtain a rejection of 90% in a membrane separation process. MWCO is expressed by Daltons (Da) and determined by molecular weights of materials with different molecular weights e.g. albumin and dextrans.

The advantages of UF membrane processes compared with conventional water treatment techniques can be listed as:

- No need for chemicals (coagulants, flocculants, disinfectants, pH adjustment)
- Since the basic principal of hollow fibers is filtration, it does not have possibility to create any waste during operation except the undesired component in the feed stream
- Provides cost reduction in waste management
- Low energy consumption
- Good and constant quality of the treated water in terms of particle and microbial removal
- Process and plant compactness

UF membranes are used in:

- Waste-water treatment

- Drinking water treatment
- Pre-treatment for desalination
- Paint recovery in the automotive industry
- Fruit juice, wine and beverage industries

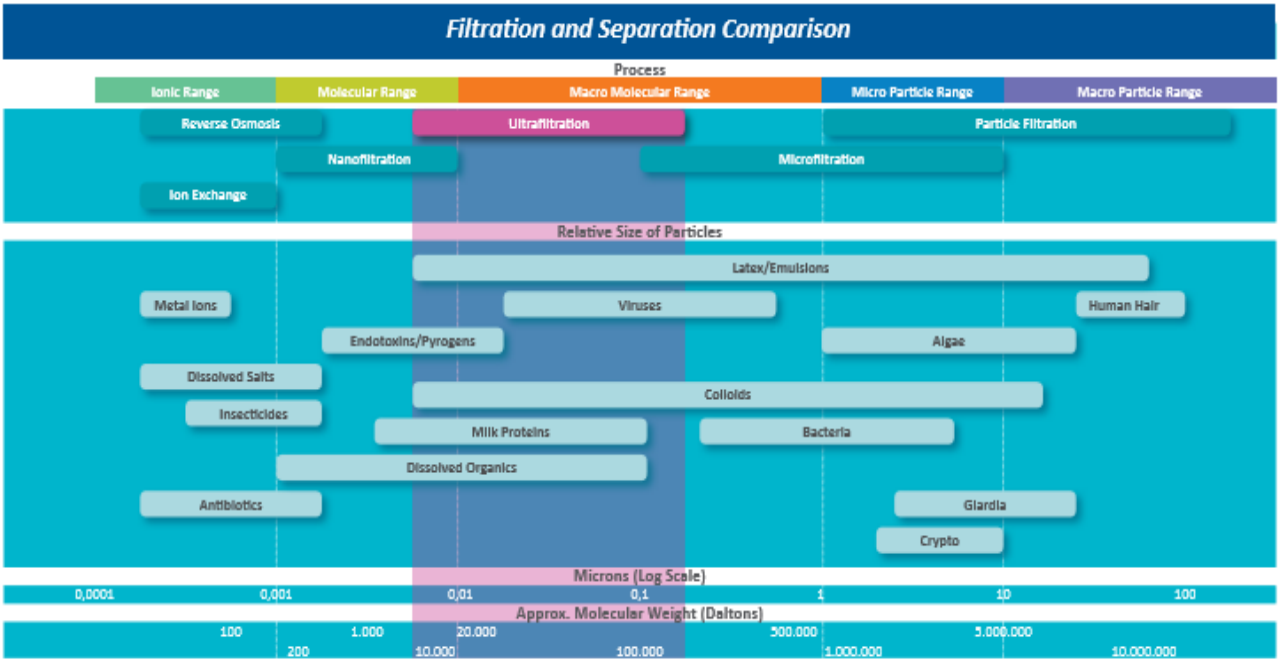


Figure 1. Membrane filtration spectrum.

2. DESCRIPTION OF AKUALYS ULTRAFILTRATION MODULE

2.1 MODULE FEATURES

The Akualys Ultra-filtration which are formed of PVDF hollow fiber membranes with high mechanical characteristics provides the following features:

- High mechanical strength, chemical resistance and thermal stability (up to 75 °C)
- Improved hydrophilicity for easy cleaning and fouling resistance during the filtration process.
- Asymmetric, dense, macro-void-free, sponge-like morphology with controlled pore size and distribution that results in high strength
- Both outside in and dead-end operation mode with an operation pH of 2-11 and operating temperature of 5-40°C
- High separation performance and high water flux (MWCO ≤150.000 Da, Flux: 45 - 180 LMH)

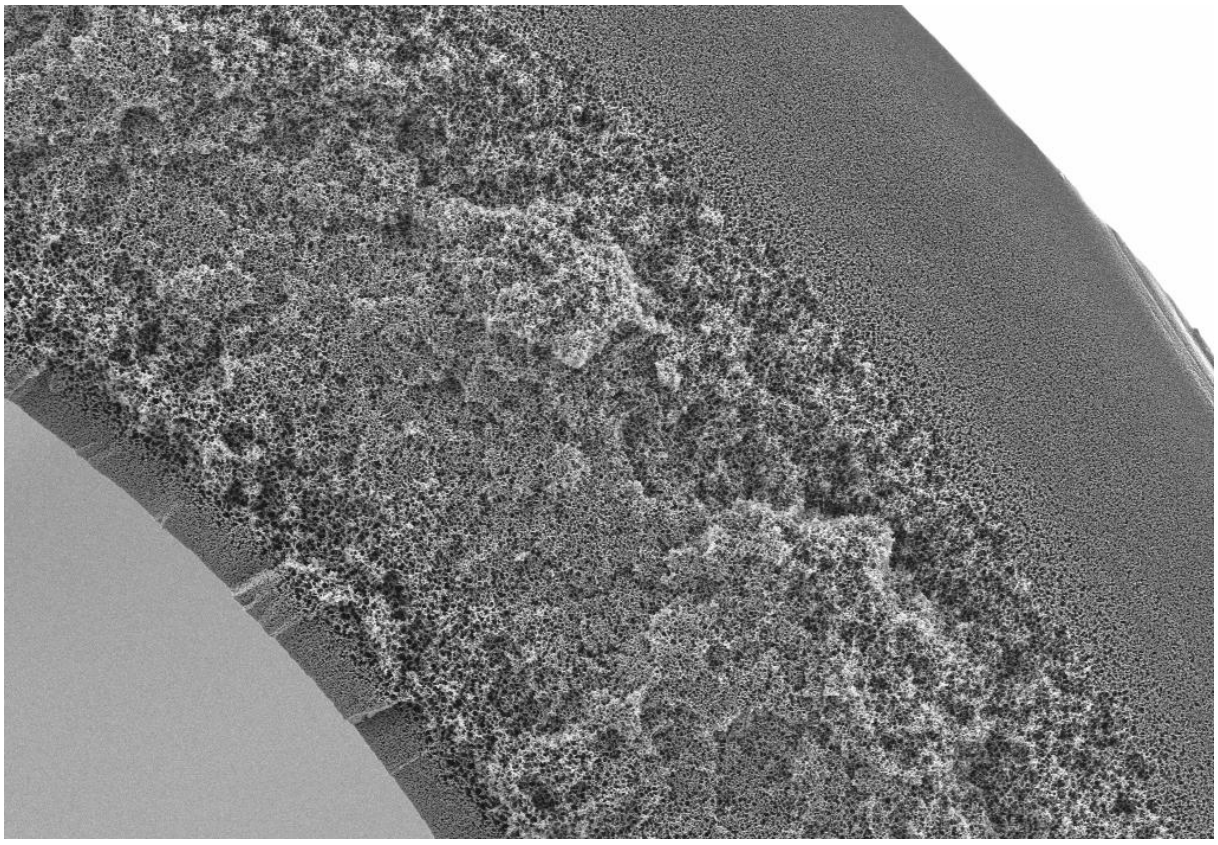


Figure 2. Cross-sectional image of the PVDF based hollow fiber membrane

Figure 3. Akualys module

2.2 MODULE SPECIFICATIONS

- PVDF based hollow fiber membranes have long life-time due to their high mechanical strength and chemical resistance.
- The capacity of clean water production is higher due to modification of membranes which enhances the hydrophilicity of membrane.
- Membrane which pore size of has 30 nm separates virus and bacteria.
- The product water quality is <0,2 NTU.

The module reference is shown in Figure 3 and its specifications are given in Table 1 and Table 2.

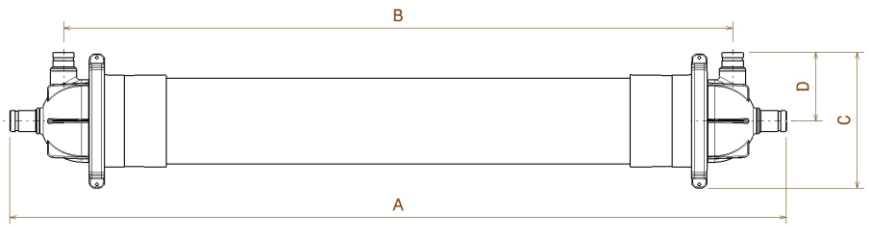


Figure 4. Akualys module reference for dimensions

Table 1. Module specifications for AGM/ASM

MODEL	Surface Area (m^2)	Dimension (mm)				Weight (kg)
		A	B	C	D	
AGM	70	2220±1	1915±1	395±1	200±1	60
ASM	35	1455±1	1151±1	395±1	200±1	35

PARAMETER	UNIT	SPECIFICATION
Name of model	-	AGM/ASM
Diameter	mm	250
Body and cap material	-	U-PVC
Nozzles	mm	DN50 - Victaulic
Potting material	-	Polyurethane

Table 2. Membrane specifications

PARAMETER	UNIT	SPECIFICATION	SPECIFICATION
Name of Model		**AGM**	**ASM**
Material	-	Modified PVDF	Modified PVDF
Membrane type	-	Hollow Fiber UF	Hollow Fiber UF
Flow direction	-	Outside to inside	Outside to inside
Fiber outside/inside diameter	mm	1,4 / 0,8	1,4 / 0,8
Active surface area	m^2	70	35
Nominal MWCO, Dextran	Dalton	≤ 150.000	≤ 150.000

2.3 MODULE INSTALLATION

When assembling the module for construction of a membrane rack, ensure that the module is not subjected to any mechanical strain (tension-free installation).

Following steps must be followed in order to ensure proper installation of the module:

1. The module must be removed from the transport packaging and checked for mechanical damage. In case of a claim, please inform your contact at AK-KİM immediately.
2. Prior to module installation, the entire system (pipes and complete rack piping) must be cleaned.
3. To ensure adequate mechanical fixing of the module in the rack mounting equipment, at least two pipe clamps with rubber protection must be provided. The connection to the rack must be fixed and vibration free.
4. It must be ensured that whilst installing the module, the connections are not subjected to twisting or stress. Check to make sure that all seals and screwed connections fit tightly.
5. **Only** glycerol must be used as a lubricant for seals, O-rings, etc.

3. SHIPPING AND STORAGE

To prevent the drying out and freezing as well as to minimize the bacterial growth the Akualys Ultra-filtration modules must be stored in a preservative solution. Preservative is automatically injected into the modules, after that all ports are sealed by plastic discs, Victaulic flanges, and plugs. The glycerol has a crucial role against freezing.

Uninstalled modules:
The modules must be stored horizontally. To prevent collapse of the packaged modules, stacking must be limited to three layers. Recommended conditions for storage are a cool, dry, normally ventilated area protected from direct sunlight and an ambient temperature of 15 to 35ºC. Sealed modules must be kept under the recommended conditions in the original packing and can be stored up to 1 year. In the UF module, 4 litres of preservative is added. If the UF module shelf duration is longer than one year from the manufacture date; please contact AK-KİM.

Storage of modules installed on a skid:

The modules must not be dried out during assembly to the skid. Drying worsens the flux capacity quickly. “Sample” modules are available for the support in assembly process.

If it is desired to ship the modules installed on the skid, the following steps must be followed:

Sodium-bisulfite preservative must be added. Then, the system must be drained to remove excess preservative and weight. The system must be resealed by closing all valves. The modules must be refilled with preservative before start.

UF systems are designed to run continuously in order to maximize the performance of the membrane system. Nevertheless, the wide-spread usage of UF systems has frequent start-ups and shutdowns. When the UF system is shutdown, the system must be cleaned by means of air-scour and backwashed with filtrate water in order to prevent bacterial growth in the UF system.

The water used for backwash before shutdown must not contain chemicals. It is advised to stop usage of any feed water and backwash chemical dosing before the last cleaning and shutdown. After cleaning, all valves on the UF system must be closed to secure the system sealing.

When the UF system shuts down, particularly in case of unplanned shutdowns, e.g. power failure or emergency shutdowns, the backpressure in the modules must be controlled in order to avoid leakage in the module housing end caps and clamps.

When the system is closed for longer than 48 hours, the following steps must be taken into consideration:
• Drying out of the module must be avoided. Dry membrane fibers get worse flux immediately.
• The system must be protected against micro-biological growth by flushing 30 to 60 minutes per day.
• The system must be protected against exposing extreme temperature.

Shutting down the UF system longer than 48 hours without adding chemical preservative and taking precautions for microbiological fouling are not advised.

Table 3. Skid shut down summary

Storage duration	Recommended Steps
0 to 48 hours	Air scour and backwash, all valves must be closed.
>2 days to 7 days	Air scour and backwash, all valves must be closed, operations must be performed 30 to 60 minutes daily or air scour, backwash, preservative must be added then all valves must be closed.
>7 days to 90 days	Preservative solution must be added and it must be renewed every three months.
>90 days	Contact to AK-KİM.

Storage of modules off skid:

If the UF system will be out of service for a long time the modules can be removed from the skid and stored. Air scour and backwash must be applied before dismantling the equipments. 10 litres of 1% sodium-bisulfite preservative must be add into the filtrate port of a module. Once the preservative is added, all inlet and outlet ports must be sealed by using victaulic flanges, plastic discs and plugs. Each module must be covered by plastic bag etc. and each module must be placed horizontal with the feed ports facing up into an individual or separate shipping box or crate. If the modules are exposed to low temperature conditions, glycerol must be added into the preservative as 20% of concentration. Modules prepared as described can be stored for 90 days. For longer storage durations, please contact AK-KİM.

4. AKUALYS ULTRAFILTRATION PROCESS DESCRIPTION

4.1 PROCESS OPERATIONS

The operation conditions for the Akualys UF modules are listed in Table 4.

Table 4. Operation conditions

PARAMETER	UNIT	SPECIFICATION	SPECIFICATION
Name of Model		**AGM**	**ASM**
Operation modes	-	Dead End / Crossflow	Dead End / Crossflow
Temperature	°C	5-40	5-40
pH	-	2 - 11	2 - 11
Filtrate flux @25°C *	$L/m^2 h$	45-180	45-180
Flow capacity**	m^3/h	3,15-12,60	1,75-6,30
Feed water inlet pressure @ 25°C	bar	2-3 (Instant Max. 5)	2-3 (Instant Max. 5)
TMP	bar	0,4 - 2	0,4 - 2
Filtrate water SDI	-	$\leq 2,5$	$\leq 2,5$
Filtrate Water Turbidity*	NTU	$\leq 0,2$	$\leq 0,2$

Normal operation process includes the operating and backwash stages. A forward flush must be used to eliminate any residual chemicals and trapped air from the module. The flush does not separate the feed water because it takes place at the outer surface of the fibers. Following the forward flush is stopped, the modules can be located in the operation mode which ranges from 20 to 60 minutes. During the operation, membrane pressure increases because of the removal of contaminants. Next, a backwashing mode takes place.

The backwashing mode realises automatically including an air scour, draining, backwash and a forward flushes. The air scour stage is used in order to remove attached particles on the external surface of the membrane. After 20-30 seconds of air scour, the module is drained by gravity in order to eliminate particles from the membrane surface.

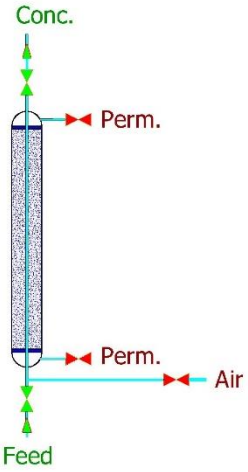
Following the draining step, the first backwash is carried out. The permeate flow is reversed from the inner surface of fibers to the outer surface. Then, the backwash flow is taken off from the module and a top draining backwash is carried out in order to remove pollutants from the region with the highest concentration.

The second backwash is carried out in order to remove contaminants from the bottom of the module. Filtrate flow is reversed from the inner surface of fibers to the outer surface. These two stages of backwashing can be repeated several times depending on the fouling. After the termination of backwashing, a forward flush is performed in order to remove pollutants and air trapped on the outer surface of fibers. Finally, the operation mode can be restart.

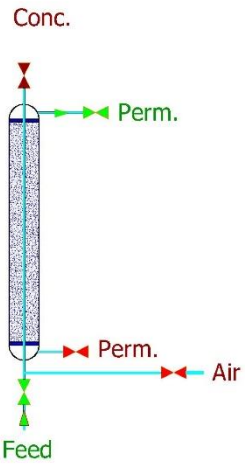
Backwash with treated/clean water at start-up proses must be advised.

CEB process is applied with caustic,chlor and acid, seperately and respectively.

1.PRODUCTION

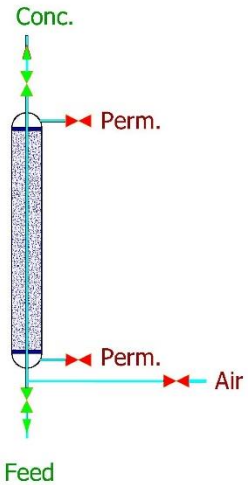


1.1 Forward Flush

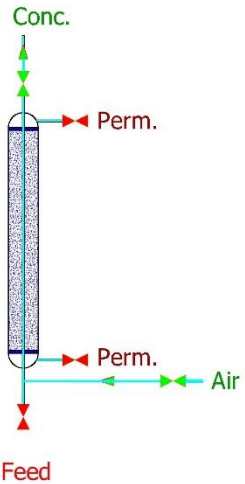


1.2 Filtration

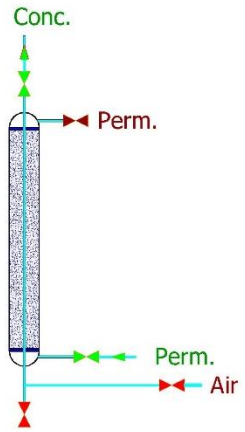
2.BACK WASH



2.1 Drain



2.2 Air Scourge



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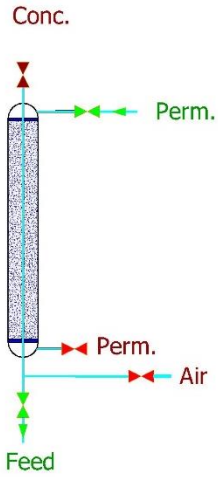

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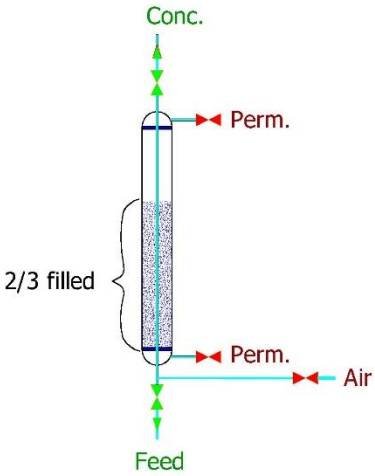
3.CEB(CAUSTIC/CHLOR/ACID)



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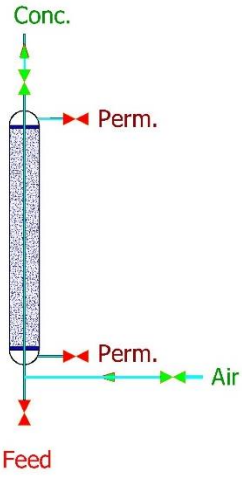
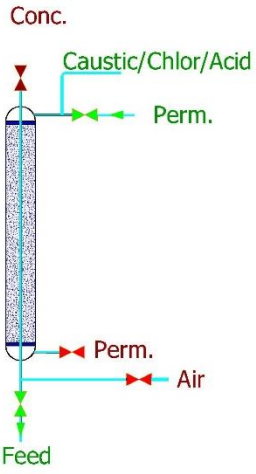


3.2 Air Scourge



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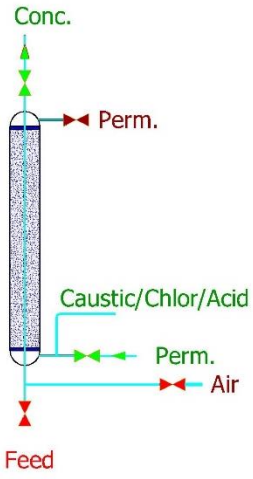

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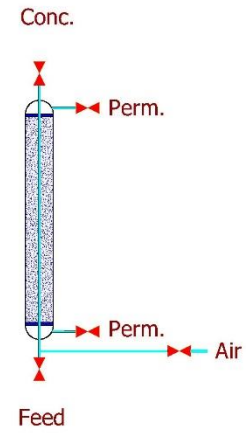
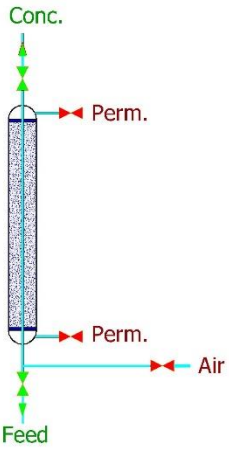
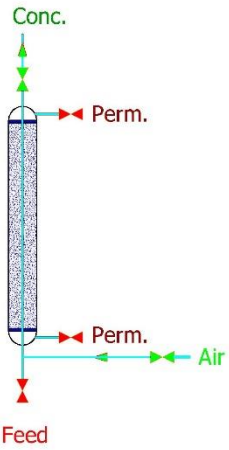


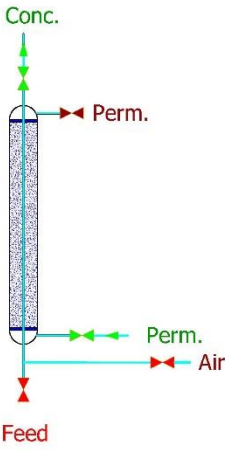
3.5 Soak



3.6 Drain



3.7 Air Scourge



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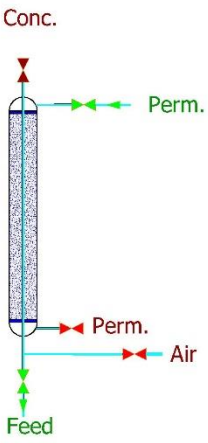

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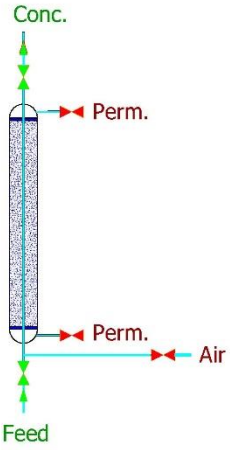

3.10 Forward Flush

Figure 5: Operation Mode

4.2 PRE-TREATMENT

Akualys UF modules are designed by considering feed water specifications given in Table 5. If the feed water quality is in excess the limit (these ranges are given below), a pre-treatment must be performed.

Table 5. Feed water specifications for AGM/ASM

PARAMETER	UNIT	SPECIFICATION
Temperature	°C	25 (Max 40)
Particle dimension	µ	< 300
Turbidity	NTU	50 (Max 250)
Oil and grease	mg/l	0 (Max 1)
pH	-	6-9
TOC	mg/l	< 10 (Max 30)
Total Suspended Solid (TSS)	mg/l	50 (Max 80)
Chlorine	mg/l	0,4 (Instant Max. 150)

Various pre-treatment processes can be performed including self-cleaning screens, bag, cartridge, disc filters, oxidation, coagulation, sedimentation, as well as media filtration.

4.3 CLEANING

The process operating parameters for the cleaning steps are given in Table 6 below.

Table 6. Summary of cleaning processes for AGM/ASM

PARAMETER	UNIT	SPECIFICATION
CLEANING		
BACKWASH		
Backwash Frequency	**Once every 20 to 60 minutes (water source or pilot test results)**	
Backwash Duration	**40 to 120 seconds**	
Backwash Flux	**100 to 150 l/m^2·h (60 - 90 gfd)**	
Air Scour	**Maximum Inlet Pressure**	**2.5 bar (36 psi)**
Air Flow per Module	**5 to 12 Nm^3/h (3 - 7 scfm)**	
Duration	**20 to 60 seconds per cycle**	
Air-Water Mix Entrance Pressure	**≤ 1.0 bar (14 psi)**	
Air Quality	**Non-oil compressed air**	
Max. backwash pressure	**bar**	**2,5 Max**
Max. air flowrate	**Nm^3/h**	**20 Max**
CHEMICALLY ENHANCED BACKWASH (CEB) / CEB process is applied with caustic,chlor and acid, seperately and respectively.		
Frequency	**As needed**	
Duration	**Backwash Time plus soak 5 to 20 minutes**	

Cleaning Solution		
Sodium hypochlorite (NaOCl)	**mg/l**	**1000**
Sodium Hydroxide (NaOH)	**mg/l**	**500**
Hydrochloric Acid (HCl)	**mg/l**	**1000**
Citric Acid	**%**	**1-2**
CLEANING IN PLACE (CIP)		
Frequency	**When the current TMP pressure is 0.9 bar higher than the first TMP Pressure (at same temperature).**	
Operation Duration	**Circulation or Filling method, 2 hours**	
Chemical Cleaning Solutions (up to pollutant)	**0,1% NaOH + 0,2% NaOCl**	
	0,2% HCl, 2% Citric acid	
Cleaning Flowrate per Module	**1-2 m^3/h**	

4.4 FOULING

There are four common fouling types for UF modules. They are listed as particulate, biological, inorganic, and organic.

Suspended solids, colloids, and turbidity are the reasons of particulate fouling. Turbidity can be reduced by coagulation, sedimentation, clarification, and media filtration. The common cleaning method for particulate fouling is air scour and backwash.

Biological fouling is the result of the growth of micro-organisms which can be reduced by using in-line chemical feed of chlorine or biocide with/or by elimination of nutrients by using

PAC, GAC, or coagulation. The common cleaning method to remove biological fouling is Chemically Enhanced Backwash (CEB) with oxidizers or biocides such as Cl_2 ,SBS.
The precipitation of inorganics on the membrane causes an inorganic fouling. It can be reduced by using oxidation or precipitation and filtration as pre-treatment to the UF or in some cases using low hardness water for the alkali chemically enhanced backwash. The common cleaning method to remove inorganic fouling is chemically enhanced backwash with acid at pH 2 (HCl, H_2SO_4, Citric Acid).

Organic fouling is the result of organics adsorbing on the membrane (silt, organic acids, humus) that can be reduced by using PAC, GAC, or coagulation. The common cleaning method to remove organic fouling is Chemically Enhanced Backwash (CEB) with alkali at pH 12 (NaOH).

5. OPERATING INFORMATION

5.1 START UP

The following procedures must be followed for the start-up of AK-KİM AKUALYS Ultrafiltration modules;

During the initial operation the equipments must be started manually.

The UF parts must be flushed in order to remove the preservative which is used in shipping or the storage solution before starting the equipment.

A filtrate flow of 60% of design must be targeted during initial operations. After 24 hours the filtrate flow can be adjusted to design conditions.

PRE-START CHECKS

1. The UF pre-treatment system must operate properly and the design requirements must be meet by the UF feed water. The chemical addition points whether are properly located and that proper mixing of chemicals in the feed streams can occur or not must be checked. Also, the addition of pre-treatment chemicals must be checked.
2. It must be verified whether the drain/ waste collection system is functional or not.
3. It must be verified whether the PLC program is available and functional or not.
4. Electrical system must be completed and then checked. It must be verified whether the instrumentation is working, and calibration is completed. Gauges and meters based on manufacturers' recommendations must be calibrated.
5. Inter-connecting piping must be cleaned and connected. System without modules must be flushed in order to remove fabrication debris. During the flushing operation, all pipe connections and valves must be checked for leaks.
6. Residual air must be removed from the system during start-up.

START UP

It must be checked that all valves are closed, and pumps are off before starting the system. The equipment must be started by following the steps below:

1. Pumps must be aligned, lubricated, and properly rotated.
2. The feed pump must be started and checked.
3. Equipment and a flush must be started and checked.

4. The backwash pump must be started and checked.
5. The backwash pressure must be set and checked.
6. The inlet air pressure must be set and checked.
7. Backwash time interval must be set and checked.
8. Air scour time interval must be set and checked.
9. Backwash sequence must be set and checked.

MODULE FLUSHING

The AK-KİM Ultrafiltration modules must be rinsed before start-up to remove preservative fluid. Flushing must be performed until no foam is observed in the wash water. Depending on the treatment application, additional rinsing or disposal of the filtrate may be needed.
NSF / ANSI Standard 61 certified modules require the following rinse processes prior to producing potable water:

1. The modules must be rinsed at a feed rate of 40 LMH minimum for a period of 4 Hours.
2. A minimum total rinse volume of 160 LMH-Hours must be achieved by using the feed water available.
3. The concentrate bleed rate must be operate from between 0% to 20% with the balance being filtrate.
4. During the rinse cycle, standard cleaning protocols must be followed as defined per the manufacturer’s recommendations (according to the feed water quality available).
5. The filtrate must be sent to the appropriate disposal system.
6. Local regulations may require additional conditioning of the system prior to producing potable water.

5.2 INTEGRITY TESTING PROCEDURES

Two methods are commonly used for integrity testing. They are listed as Bubble Test and Pressure Hold/Decay and defined below.

BUBBLE TEST

Modules with leakage can be found using a skid pressure hold test. The test steps are defined below;

1. The module must be taken out of the filtration mode.
2. The module must be drained from the feed side.
3. Feed and concentrate valve must be closed.
4. Filtrate valve must be aligned to allow flow to drain through the transparent tube.
5. The drained side of the module must have pressurized with oil-free compressed air from the air inlet valve, and the air pressure must be set to a maximum of 2 bars (29 psi).

If large continuous air bubbles are observed, it means that the module has broken fibers/ leakage. Smaller and infrequent bubbles are the result of air diffusion through the pores of the ultrafiltration membrane.

PRESSURE HOLD/DECAY

1. The UF unit or module must be taken out of the filtration mode. The water must be drained from the feed side of the module. The feed and concentrate valves must be closed and checked. Then, the filtrate valve must be kept open.
2. The membrane module must be pressurized with oil free compressed air from the air inlet valve, and the air pressure must be slowly increased to the air pressure to a maximum of 2 bars (29 psi).
3. The air inlet valve must be closed.
4. The pressure must be hold for 5 minutes. The membrane is integral (no leaks) if the pressure drop is lower than 0.2 bar (2.9 psi). If the pressure drop is greater than 0.2 bar in 5 minutes (2.9 psi in 5 minutes) then membrane fibers are compromised and need to repair.
5. Following the “fiber test and repair procedure” the membrane must be repaired.

5.3 SHUT DOWN

MANUAL SHUT DOWN

For manual shut down, the concentrate rinse valve must be opened and flushed for 15 seconds. Then the inlet valve must be slowly closed.

EQUIPMENT SHUT DOWN DURING AUTOMATIC OPERATION

In the case of that the feed pump did not start when operation was initiated, or the inlet or filtrate pressure is too high to operate, the equipment would stop or would not allow automatic operation.

LONG TERM EQUIPMENT SHUT DOWN

If the equipment is down for more than two days, operation for 30 to 60 minutes per day can protect the equipment from bacterial fouling.

If the equipment is down for more than seven days a manual air scrub must be applied before turning off the equipment, a storage solution must be added (1% NaHSO3), and all valves must be closed.

During long term storage, pH value must be checked every 30 days. The storage solution must be replaced if the pH value is less than 3. (<3).

During shut down period, the UF membrane must be kept wet. The membrane components will be irreversibly damaged in case of drying out.