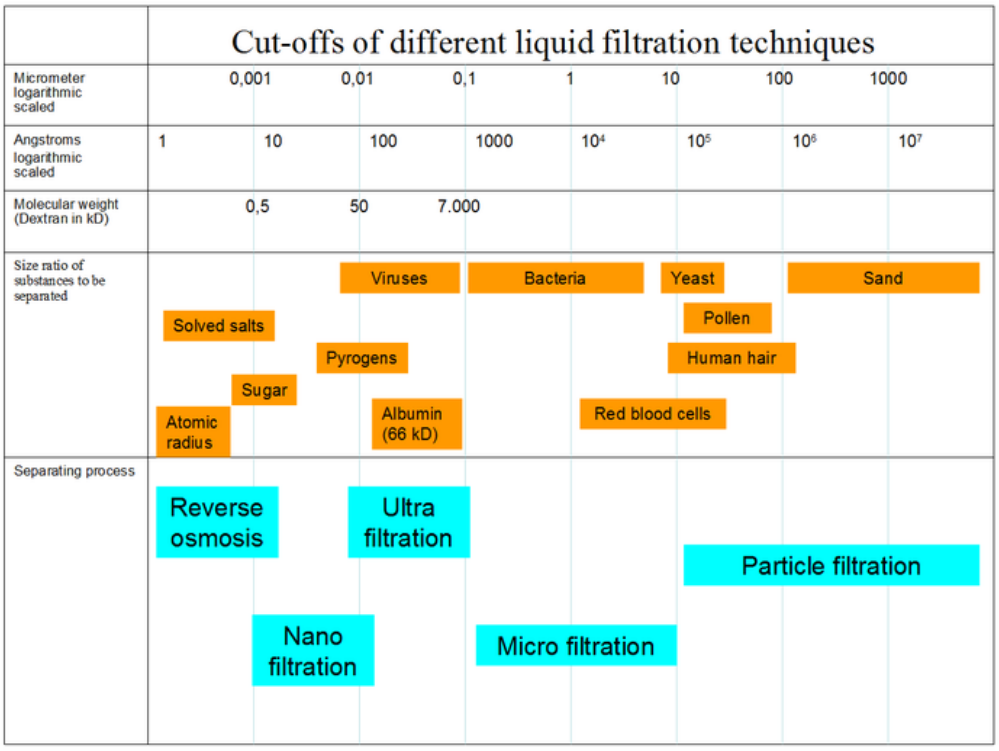
1 C-MEM™ Process Description

C-MEM™ is a unique membrane based filtration process developed by SFC Umwelttechnik in the range of micro- and ultrafiltration. In general it can be used for treating drinking water, secondary treated wastewater as well as wastewater. Membrane filtration systems can be classified depending on material of filter membranes (organic, inorganic), on whether they are out of water or submerged and on operation mode such as “inside- out”, “outside-in”, “dead-end”, “cross-flow” and so on. C-MEM™ shall be classified as an organic hollow fibre submerged system with “outside – in” operation.

Ultrafiltration (UF) is a variety of membrane filtration in which forces like pressure or concentration gradients leads to a separation through a semipermeable membrane. Suspended solids and solutes of high molecular weight are retained in the so-called retentate, while water and low molecular weight solutes pass through the membrane in the permeate. This separation process is used in industry and research for purifying and concentrating macromolecular (10^3 - 10^6 Da) solutions, especially protein solutions. Ultrafiltration is not fundamentally different from microfiltration. Both of these separate based on size exclusion or particle capture. It is fundamentally different from membrane gas separation, which separate based on different amounts of absorption and different rates of diffusion. Ultrafiltration membranes are defined by the Molecular Weight Cut Off (MWCO) of the membrane used. Ultrafiltration is applied in cross-flow or dead-end mode.



1.1 C-MEM™ System

The basic principle of the filtration is that porous organic hollow fibre membranes with micro-pores are used as basic filtration media.

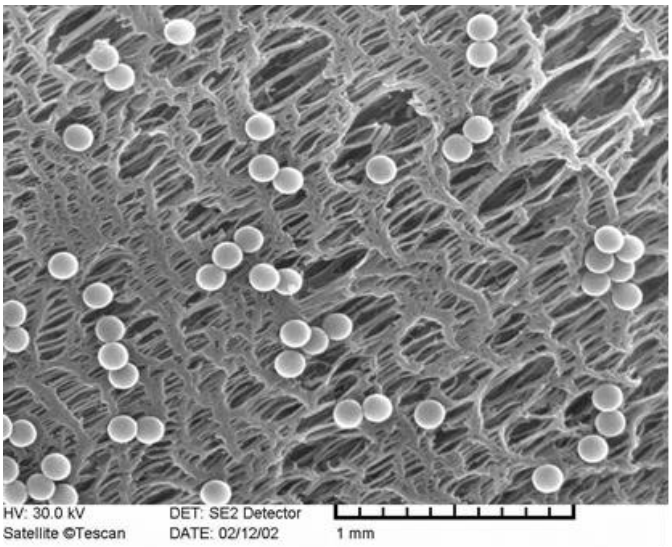


Figure 1: REM picture of membrane surface of C-MEM™ hollow fibres with retained bacteria

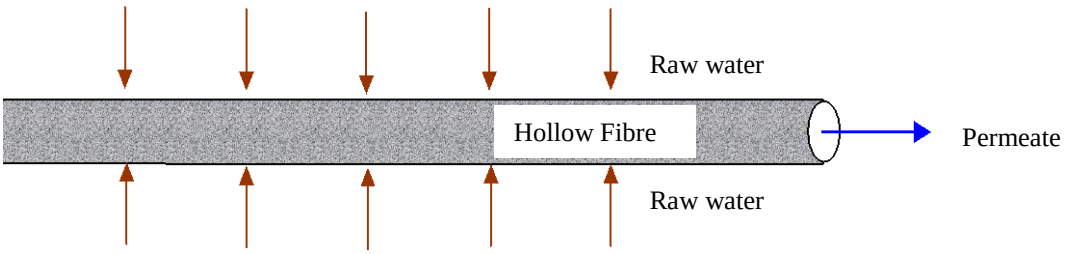


Figure 2: Schematic picture of C-MEM™ Hollow fibres for „outside – in operation"

The fibres (**Figure 2**) show outside diameters of less than 1 mm (0.3 - 0.5 mm depending on application).

In order to obtain sufficient surface area and to allow constant fluxes several hundred of parallel fibres (1-3m long depending on application) are combined to bundles and are wound up around a carrier cartridge (**Figure 3**).

The carrier cartridge has a suction connection for filtered water (top) and a pressure air connection for air scour (bottom) which allows cleaning the fibers from outside simultaneously to normal operation.

About 100 of such cartridges are combined in one module where air scour and filtered water connections are given and are connected to individual service pipes and valves.

Figure 3: C-MEM™ cartridges

In larger plants modules (**Figure 4**) are grouped together in order to allow economical operation and connection to the filtered water, backwash water, backwash air, air scour and CIP cleaning system. Modules are finally submerged into a filter basin where raw water is filtered through the C-MEM™ system.

Figure 4: Typical Module arrangement

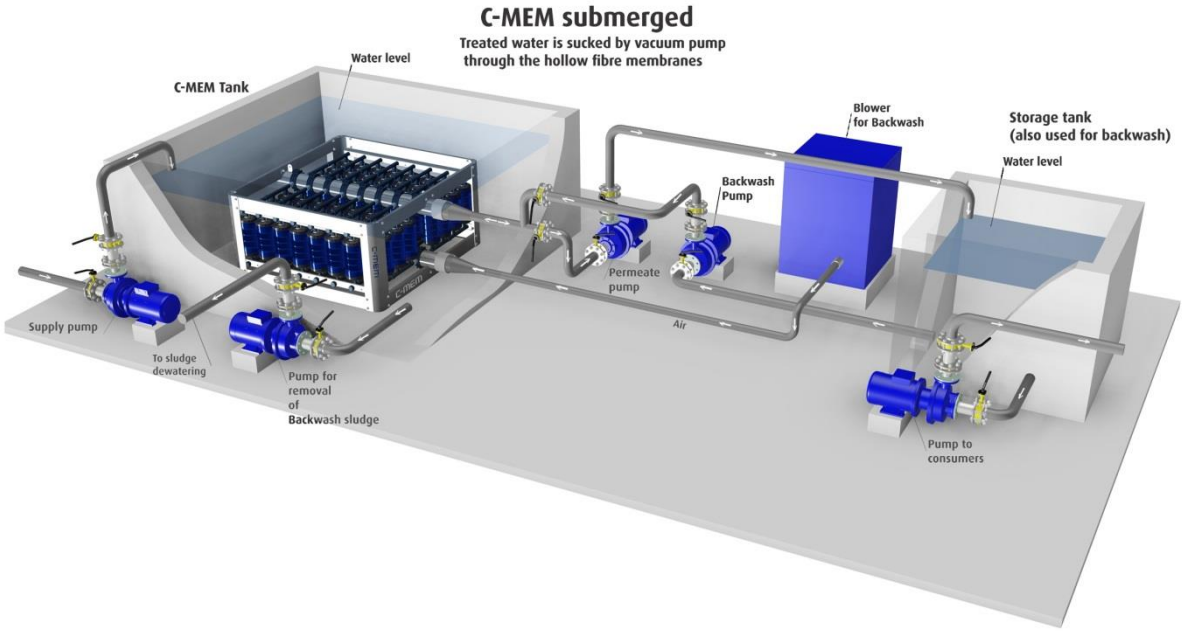


Figure 5: Typical C-MEM plant arrangement

1.2 Description of Operation

During normal operation all modules are operated in the production mode: via the under pressure from the suction pump the membranes produce filtrate through the hollow fibres in “outside-in operation”. Periodically the air scour system will prevent the fibres from clogging and will prolong the normal operation mode of a module (or a group of modules).

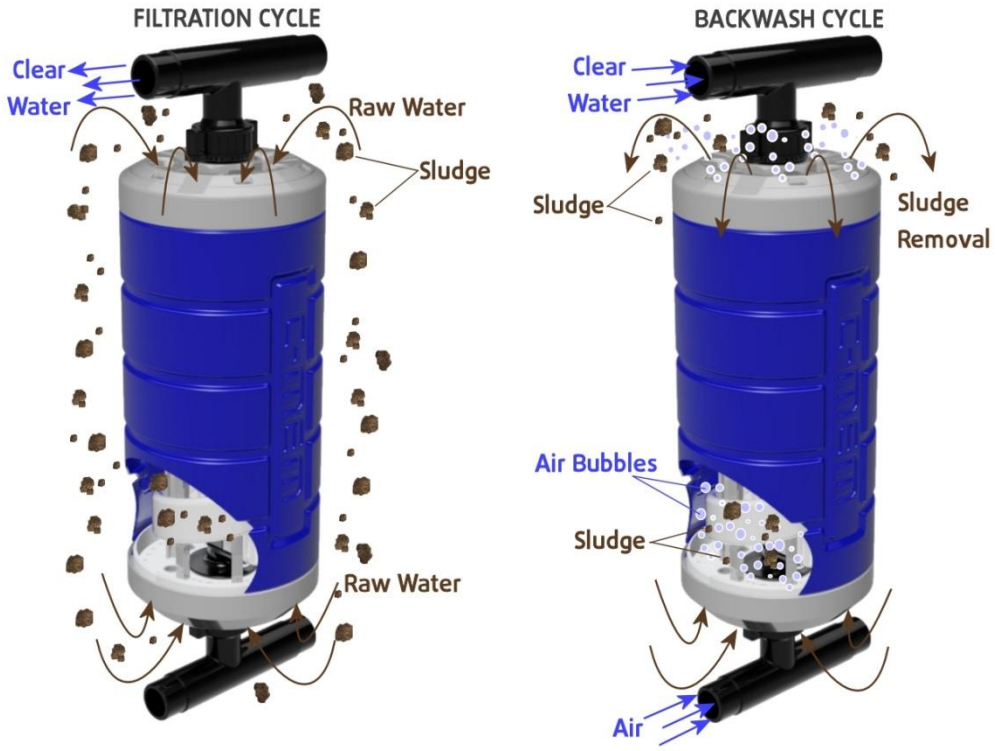


Figure 6: Module in "production mode" (left) and module during “inside-out mode”

Once the filtration capacity of one module (group of modules) has arrived at a certain minimum value or transmembrane pressure has arrived at a certain maximum, the backwash procedure consisting of air and water backwash cycles will clean the clogged membranes in “inside-out mode”.

Periodically (for example once a week) scaling of the membranes should be removed by using the clean in place CIP cleaning.

CIP cleaning will be done inside out module by module while other modules can remain in normal operation. Modules can be shifted into a separate chemical cleaning tank for that purpose or stay in the filtration tank.

1.3 Control System

The complete operation of the plant is controlled by PCS. Operation and air scour as well as backwash mode cycles are programmed and can be operated via the automation system. A remote device for assistance is provided, which requires a stable telephone or internet connection to site.

1.4 Operational Costs

The C-MEM™ system offers lower operational costs compared to competitors due to following reasons.

1. Permeate pumps, backwash pumps and blowers will be equipped with adjustable frequency in order to optimize energy consumption.

2. Pumps and blowers will be supplied with optimized energy consumption.

3. Membrane aeration cycles are very short, e.g. 15 sec per 10 minutes. The rest of the time the blower can be used for aeration of the bioreactor. So an additional process air blower will be smaller or even not necessary.

4. Cleaning chemicals will work in higher efficiency during CIP of membranes as they are injected in the closed membrane cartridge. This will avoid any dilution of chemicals during cleaning and will save overall amount of chemicals.

1.5 Quality Assurance and Integrity test during Operation

The C-MEM™ system is offered with an integrity test system in order to spot leakages in the membrane system during operation without disassembly of membrane system. This includes turbidity measurement as well as pressure decay tests.

2 C-MEM™ Process Advantages

2.1 Comparison to other Filtration & Disinfection Systems

Conventional filtration / disinfection consist of sand or other media filters followed by disinfection with appropriate oxidation agents (chlorine, chlorine dioxide, hypochlorite solutions, UV or ozone).

The following general differences to C-MEM™ membrane filtration are important:

- ✓ Media (sand) filtration normally does not allow retaining particle sizes smaller than 5-10 micron. C- MEM™ filters have pore sizes of 0.05 micron to remove bacteria and virus as well.

- ✓ Bacteria and virus are not safely retained by a media filtration system. This holds especially true for parasites such as giardia or cryptosporidium cysts.

- ✓ Disinfection with any disinfectant does not remove organisms, it only inactivates them. The effect depends on the amount of disinfectant used, the quality of filtration applied, the retention time available for oxidation and the existence or non-existence of other competing reaction partners (scavenging). Dead microorganisms are nutrient for other microorganism, thus lead to strong regrowth in the distribution network.

- ✓ C-MEM™ does remove bacteria and virus up to a degree of 4-7 log removal (10^4 to 10^7 times reduction), independent of type or life form of organism.

- ✓ C-MEM™ does not produce disinfection by-products or bad odours.

- ✓ C-MEM™ also removes typical wastewater TOC (total organic carbon) components to a large extent (60 % is a typical figure).

2.2 Comparison to other Membrane Filtration Systems

- ✓ C-MEM™ fibres are protected in cartridges and are not subject to sudden mechanical termination.

- ✓ C-MEM™ cartridges allow higher fluxes and protect the fibres from frequent clogging through the air scour system!

- ✓ Other submerged fibre systems use longitudinal arrangement of the fibres in the process tanks with coarse bubble aeration from underneath to allow for outside cleaning. In this configuration the cleaning effect is minor and only energy consuming.

- ✓ C-MEM™ fibres and cartridges allow having more equal distribution of applied pressures and flows because they are within a small range of hydrostatic pressure difference (only about 40 mbar compared to up to 200 mbar pressure difference in other systems).

- ✓ The C-MEM™ module significantly reduces the footprint and space requirements of the overall application.

- ✓ C-MEM™ cartridges are comparable light and can be lifted much easier than conventional plate or hollow fibre systems. Furthermore the cartridges can be installed in variable configurations according actual requirements.

- ✓ C-MEM™ cartridge will allow cleaning chemicals to work directly on the membrane without any dilution in the surrounding media.

- ✓ The handling of the C-MEM™ system is much easier due to the light and small constructions of cartridges and modules.