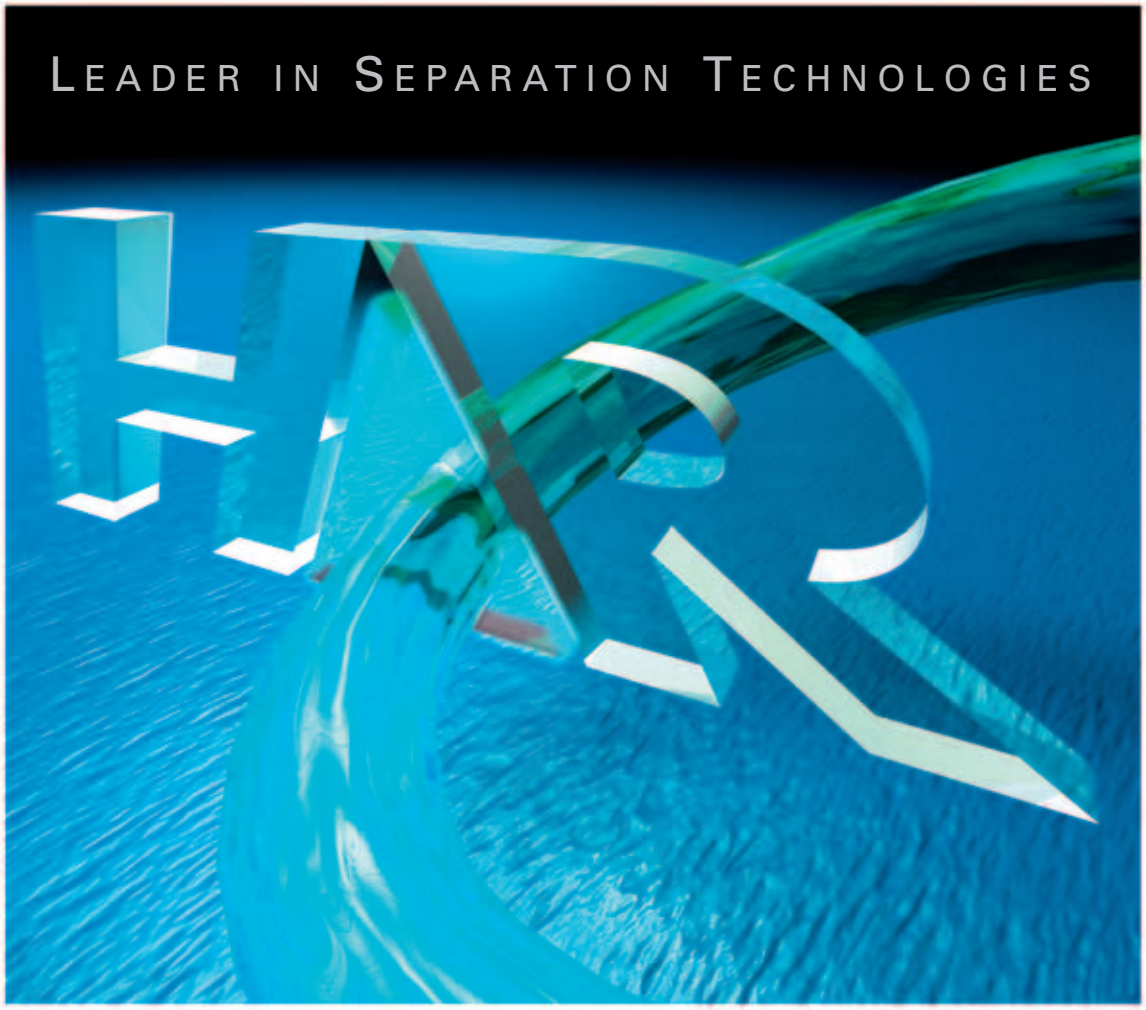


HAR®

HYDRO AIR RESEARCH

MEMBRANE SEPARATION SYSTEM

ICIM CISQ IQNet

ISO 9001 - Cert. n° 0711

PROCESS

Hydro Air Research Italia

Since 1979 HAR has gained extensive expertise in process and waste water applications, becoming a leader in membrane separation technology.
Over 10% of HAR annual revenues are devoted to the company's research and development efforts. The result is an on-going technological upgrading of its products and applications, including separation technologies such as evaporation/crystallization, electrodialysis, chromatography and pervaporation.

HAR pursues ISO 9001 Quality Policy, to enable the maximum satisfaction of its customers by responding appropriately to their needs and requirements.

Industrial process applications include biotechnology and pharmaceutical applications, where HAR developed its own know-how, as well as applications in food and dairy, fine chemicals, petrochemical and chemical field.

According to the increasingly stringent environmental legislation, HAR designs and supplies complete plants "Zero Discharge Water Recycling", an advanced process to treat effluents obtaining water suitable to reuse or to discharge according to the law restrictions. The goal is reached through the combination of different technologies, from bioHAR® Membrane Bioreactor through membrane processes, pervaporation and evaporation.

HAR has developed and realized patented systems for Landfill Leachate Treatment, plants with an economical process, effective and reliable.

HAR approach to separation problems

The beginning of all HAR systems design is the evaluation of the customer's objectives and requirement. Test facilities and pilot plant are available for feasibility study and bench or semi-industrial trials.

Preliminary tests are carried out in HAR laboratories on small liquid samples providing separation performance and data useful for industrial plant scale-up as well as cost projections or economic models to determinate full-scale operation and required capital costs.
Pilot plant verification at customer's site is recommended to generate data under actual field conditions.

Technologies

Membrane

Membrane technology can be used in a wide range of separation processes.
HAR expertise covers all the range of membrane processes, from Microfiltration and Ultrafiltration through Nanofiltration and Reverse Osmosis to Electrodialysis.
Depending on the purpose of the separation, different type of membranes can be used, characterized by different material of construction, configuration and selectivity.
Organic and inorganic membranes, spiral wound and hollow fiber, tubular and plate type can be selected depending on the application and on process requirements.

Chromatography

Considering the increasing demand on products purity levels, specially in biotechnology, food and pharmaceutical field, chromatographic separation is the most powerful of separation technologies for purification processes, mainly for impurities that are difficult to separate by conventional separation methods.
HAR activity includes process feasibility through pilot testing, design and manufacturing of chromatographic columns.

Ion Exchange

Many kinds of substances can be purified by ion exchange treatment with specific resins. The separation goal is pursued through different techniques, based on complex ion formation, ion exclusion, affinity difference, selectivity difference or ion retardation.

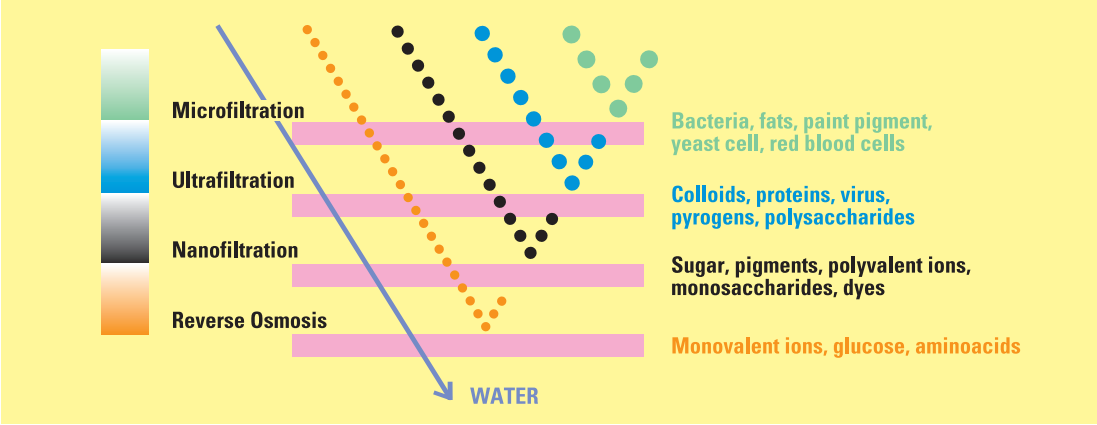
Evaporation / Crystallization

HAR continuous evaporation systems use a wide range of technologies: single or multieffects, forced circulation, falling film, thin film with thermal compression or mechanical vapour compression. When designed as crystallizers for chemical, pharmaceuticals or food industry the engineering of the equipment guarantees product quality and long operating cycles.

Pervaporation

A low pressure, low temperature membrane process for organic solvent drying and concentration. An optimal process to break azeotropes and solve bottlenecking problems.

Membrane Technology



Microfiltration is the most open cross-flow filtration device. Typical application of this low pressure process is the clarification of chemical, biological, pharmaceutical or food solutions, for the removal of high molecular weight compounds such as bacteria, fats, yeasts and fungi.

Ultrafiltration is a low pressure process for selective filtration of molecules of specified size and weight, typically in the range from 1000 MW to 1.000.000 MW. Typical applications of UF membrane are concentration and recovery of high molecular weight compounds separation/removal of contaminants, clarification, removal of colloids and suspended solids.

Nanofiltration is a pressure driven process similar to RO applied in the area between RO and UF. Monovalent ions and low molecular weight organics are passing through the membrane, while bigger compounds are rejected. MW cut off of a NF membrane is in the range 150-500 and typical application is in pharmaceutical preparations, removal of colour, of hardness from water.

Reverse Osmosis is a high pressure separation process to remove low molecular solutes (salts, small organics molecules) from a solvent (water).
The separation occurs with an imposed pressure higher than the osmotic pressure, forcing the solvent to pass through the membrane while the solute is rejected, monovalent ions included.

The large variety of membranes and modules in all commercial configurations (tubular, spiral wound, hollow fiber, plate and frame) as well as manufacturing materials (polymeric and inorganic) provides numerous alternatives allowing to solve most separation problems with custom made systems.

HAR technical specialists work with the end-user in order to satisfy the widest spectrum of requirements in terms of application, volume and rules, tailoring the system on the customer's needs.

The extensive design, engineering, manufacturing and quality assurance capabilities as well as the experience in thousands of industrial systems combine to produce the most competitive cost efficient membrane systems.

Depending on the type of operation (i.e. batch or continuous) and the extent of interface with existing equipment required, the operating system controls are ranging from a simple manual or programmable logic control (PLC) to a distributed control system.

System design and components selection criteria are evaluated function to each specific process, ensuring that safety standards are incorporated such as explosion proofing, ATEX compliance, analytical process detection, CIP and/or SIP, full automatic sequence, full or partial animation of the process, data logging to PC, sanitary requirements, GMP criteria and FDA approval.

Special membranes can be used to concentrate and desalt small organic solutes in a wide spectrum of organic solvents, for pharmaceutical/chemical processes or waste treatment applications.

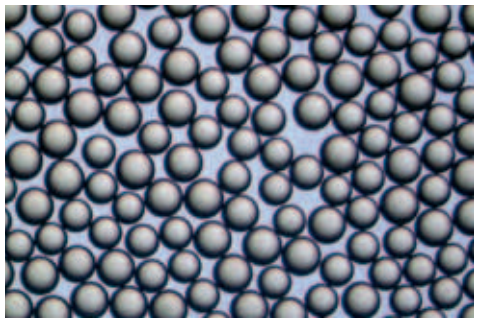
Chromatography

Developing a chromatographic or adsorptive purification technology for a target product involves three steps:

- selection of media and scouting for suitable protocol
- optimizing media and column performance for defined separation objectives
- scale-up and operation of the production scale system with SOPs and validation procedures

In a collaborative effort with international institutes and adsorbent manufacturer, HAR built an expertise in designing processes for different industrial chromatographic separations for molecules from antibiotics, natural active ingredients of plant origin, synthetic peptides, synthetic APIs, to macromolecules like enzymes, antibodies and plasmid DNA, DNA and RNA.

Resins offered by HAR are rich in range of interactions as well as range of particle and pore sizes; they offer advantages like rigidity and stability to autoclaving and



harsh CIP (cleaning-in-place) and SIP (sanitization-in-place) procedures.

Considerable work has lead HAR to design column hardware for both packed bed and expanded bed format of adsorption chromatography. Packed bed and expanded bed purification technologies have been developed for molecules from penicillin G, rifamycin, vitamin B12, and ß-carotene to proteins like lactoferrin, lactoperoxidase, lysozyme, insulin etc.

HAR offers laboratory scale to plant scale column chromatography setups complete with column, pumps, piping system and measurement & controls.

HAR is also proposing of a new variant of expanded bed adsorption that attempts to overcome all disadvantages of packed bed and expanded bed operations.
Fluidized Moving Bed (FMB) is a combination of expanded beds of adsorbent mounted above each other in the form a single composite column. The distinct sections individually handle different operations like adsorption, washing, elution and regeneration in a sequential manner with the adsorbent always moving countercurrent to the different mobile phases in different sections. The concept of FMB is useful in large scale separations like in whey or soya protein recoveries, recovery of carotenoids from palm oil and in antibiotic purifications, lowering adsorbent inventories while providing better solid-liquid mass transfer rates and high productivities on adsorbents used.

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Pervaporation

Pervaporation is a low pressure, low temperature membrane process for organic solvent drying and concentration.
Pervaporation or vapour permeation (depending if the separation is performed in liquid phase or gas phase) is an optimal process to break azeotropes and solve bottlenecking problems at competitive costs.
It offers the possibility to separate miscible liquids of similar molar mass and it is an alternative method to distillation, overcoming the limitations of standard distillation in presence of azeotropes. Pervaporation technology can offer considerable savings both in terms of costs and performances.

- The solvent can be concentrated down from any water level to very low water content
- Azeotropes are easily broken
- Membranes are highly selective and offer a continuous high flux operation
- Water produced is highly pure and can be reprocessed
- It is a low energy process

Batch pervaporation is a simple system with great flexibility, however a buffer tank is required for batch operation. Continuous pervaporation operates best with low impurities in the feed and is best for large capacities. Vapor phase permeation is preferred for direct feeds from distillation columns or for streams with dissolved solids

The membranes used in pervaporation processes are classified according to the nature of the separation being performed.
Hydrophilic membranes are used to remove water from organic solutions.
Organophilic membranes are used to recover organics from solutions.

Established industrial applications of pervaporation include:

- Treatment of wastewater contaminated with organics
- Recovery of valuable organic compounds from process streams
- Dehydration of organic solvent-water solutions
- Harvesting of organic substances from fermented broth

Other products separated or purified by pervaporation include alcohols (methanol, ethanol, propanol, buthanol, benzyl alcohol), ketones (acetone, MIBK), aromatics (benzene, toluene, phenol), esters (methyl acetate, ethyl acetate, buthyl acetate), amines (triethylamine, pyridine, aniline), aliphatics (chlorinated hydrocarbons) and ethers (THF, dioxane).

Applications

Pharma / Biotech

HYDRO AIR RESEARCH membrane systems are operating successfully in downstream processing for antibiotics and biological active principles extraction from fermentation broths including such products as Cephalosporin, Erythromycin, Penicillin, Clavulanic Acid, Tetracycline and others.
The systems, when compared with the conventional rotary precoat filters often used in this service, are superior in terms of product yield, filtrate quality, operating costs and waste problems.

Other applications include:

- Extraction, purification and concentration of antibiotics, vitamins, organic acids
- Antibiotics recovery from organic solvents using solvent stable membranes
- Pyrogen removal from biological liquids
- Cell harvesting: concentration-diafiltration
- Sterilization of nutrients liquids
- Cell debris removal
- Viruses, proteins, polysaccharides, enzymes concentration-purification
- Spent broth concentration/evaporation

HAR system for antibiotic recovery

STEP 1 - BROTH CLARIFICATION
Ceramic cross-flow system

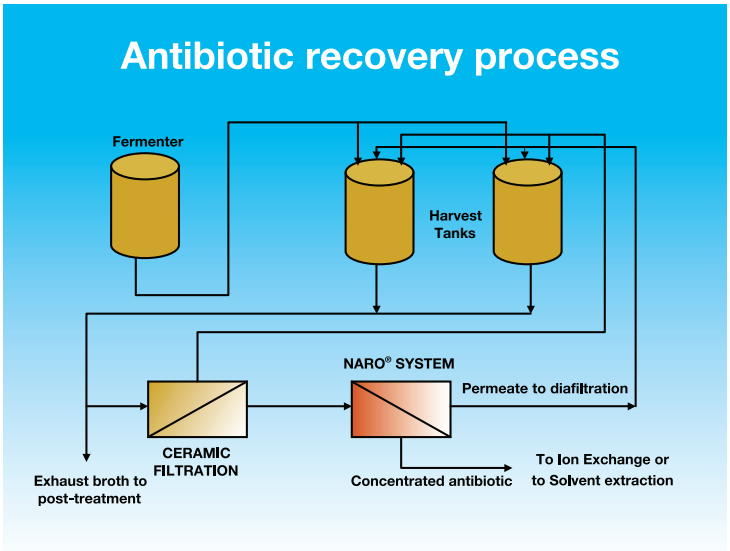
- More than 95% activity recovery
- Filtrate of sparkling quality
- Excellent protein removal
- High permeate flux

STEP 2 - CONCENTRATION
NARO® system

- Active principle concentration while desalting
- High yield
- High concentration factor

Proven experience in downstream processing

- Amikacin
- Acarbose
- Adriamycin
- Cephalosporin-C
- Cephalexin
- Clavulanic Acid
- Daptomycin
- Daunomycin
- Enzymes
- Erythromycin
- Gibberellic Acid
- Lactoferrin
- Lysergic Acid
- Kanamycin
- Rifamycin
- Penicillin-G
- Steroids
- Tetracyclin
- Vancomycin
- Vitamin C
- Vitamin B12
- 6-APA
- 7-ACA
- 7-ADCA



Applications

Chemicals & Fine Chemicals

- Polymers concentration/recovery
- Brine purification
- Catalyst recovery
- Solvents clean-up
- Solvents exchange
- Acids concentration/purification
- Glycerine purification
- Pesticides removal from effluent

Solvent resistant membranes

HAR is able to design and manufacture complete systems for purification and/or concentration processes in presence of organic solvents, by means of different membranes suitable for the purpose.
HAR can offer access to a range of new Organic Solvent Nanofiltration membranes suitable for use in non-aqueous applications.
Typical applications for these membranes in the pharmaceutical and fine chemicals industries are solvent exchange, catalyst recycle, organics recovery and products purifications.

Food and Dairy

- Milk concentration
- Whey fractionation/concentration
- Fruit juice clarification/concentration
- Sugars clarification/concentration
- Food dyes desalting/concentration
- Gelatine concentration
- Pectin concentration
- Vinegar clarification
- Wine clarification/concentration
- Coffee concentration
- Beer recovery from bottom tanks

Cosmetic & toiletries

- Removal of emulsions, surfactants, COD, BOD, to meet discharge limits.

Laundry

- Recovery of surfactants and clear water recycle.
- Pollutants removal from commercial laundries waste streams and water recycle.

Textile & Dyehouse

- Water recovery
- Colour removal
- Removal of dissolved and suspended materials including COD, BOD, dyestuff/colorant, salt

Metal finishing metalworking

- Recovery of metals salts from rinse streams - Machining coolants
- Waste treatment (rolling, drawing & casting waste water, air compressor blow-down condensate, cleaning fluids, oily emulsions, paint and ink wash down fluids)

Tanneries, Wood, Pulp & Paper

- Proteic material and sulphide recovery
- Water recovery and waste minimization
- Tannic acid concentration

Reclamation of caustic and acid from CIP solutions

Spent caustic and / or acid solutions, contaminated by suspended and dissolved organic substances, can be treated with specific membranes, able to remove the contaminants.
Because of a high selectivity the filtrate solution is very clean, suitable for reuse.

Bioethanol

- Membrane bioreactors in fuel ethanol production

Oil-water separation

- Treatment for on-shore and off-shore oil field produced water
- Produced water clean-up for disposal or reuse (< 1 ppm soluble oil)

HYDRO AIR RESEARCH
MEMBRANE SEPARATION SYSTEM

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