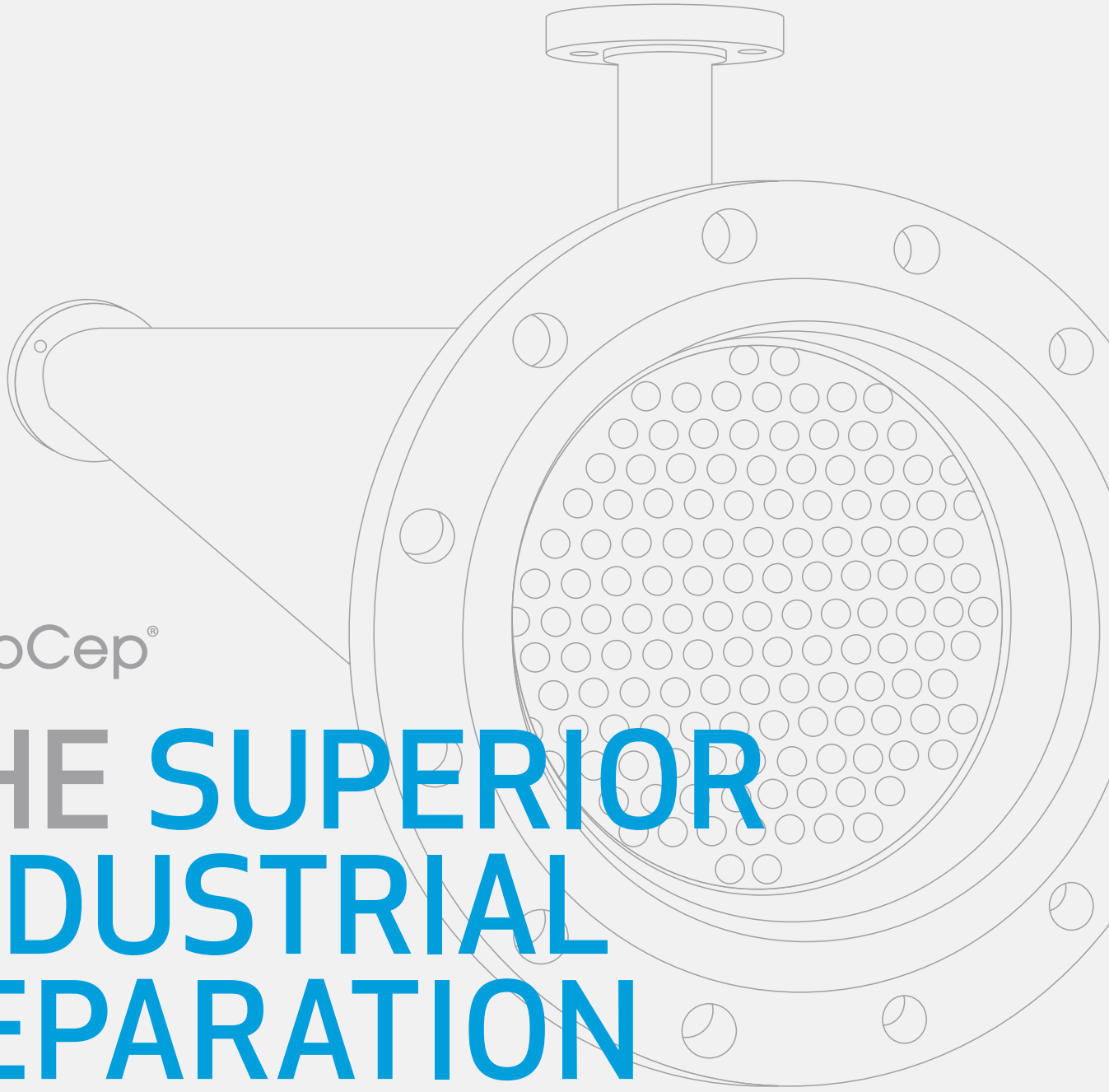


FerroCep®

THE SUPERIOR INDUSTRIAL SEPARATION SOLUTION

Hyflux®

EXCEPTIONAL DURABILITY IN EXTREME PROCESS CONDITIONS

Designed and engineered to handle high viscosity feeds, Hyflux's FerroCep® stainless steel membranes have the durability to withstand extreme operating conditions. Experience a superior level of performance and reliability with one of the world's toughest membrane products.

Product Features and Benefits

- High temperature, pressure and pH tolerance
- Resistant to corrosion
- Unique seamless fabrication
- Large diameter tubes

Operation Features and Benefits

- Proven long service life
- Sterilisable with steam
- Impervious to mechanical shock
- Compatible with high solids, viscous streams

Key Applications

- Fermentation broth clarification
- Starch processing
- Emulsified oil wastewater treatment
- Juice and syrup clarification

FERROCEP® APPLICATIONS

FerroCep® stainless steel membranes may be applied for various uses, including:

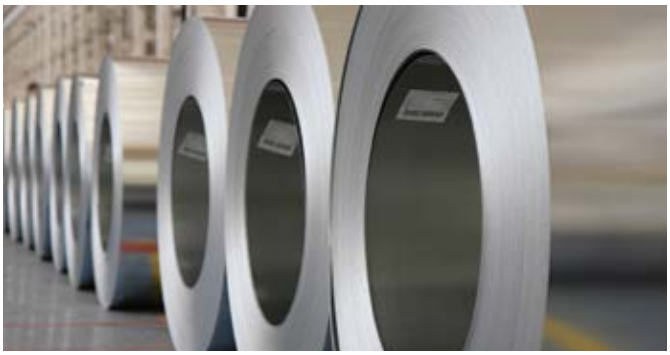
Fermentation Broth Clarification

- Production of antibiotics, vitamins and amino acids in pharmaceutical industries

Starch Processing

- Recovery of potato and rice starch from waste streams
- Concentration of corn starch to produce corn extract

Emulsified Oil Wastewater Treatment



- Recycling of degreasing solutions in steel industry
- Wastewater treatment for metal finishing industries

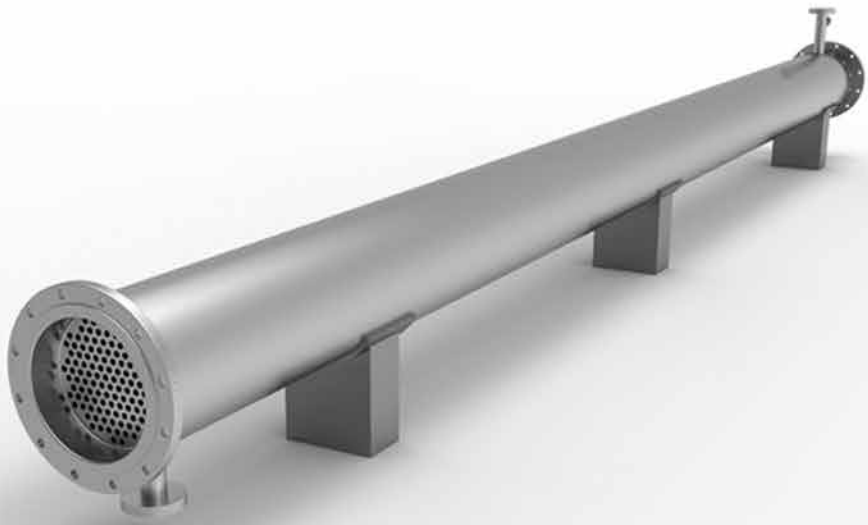
Juice and Syrup Clarification

- Production of organic cane sugar
- Clarification of fruit and vegetable juices

01 FERROCEP®
THE SUPERIOR INDUSTRIAL SEPARATION SOLUTION

THE SUPERIOR INDUSTRIAL SEPARATION SOLUTION

With its stainless steel material's chemical and structural properties, FerroCep® handles extreme operating conditions with ease, providing superior filtration performance for industrial separation processes.



Hyflux's FerroCep® stainless steel membranes offer a solution to many industrial filtration needs where high concentrations of chemicals, suspended solids and contaminants make other membrane separation methods unsuitable. In fact, FerroCep® has proven effective for highly viscous streams or separation processes that have to take place at elevated temperatures and pressures.

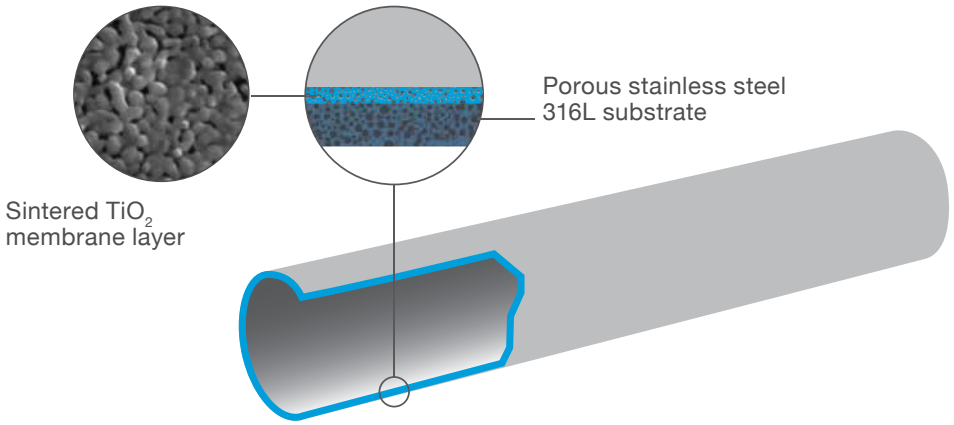
Manufactured in Singapore, FerroCep® combines the process durability of the stainless steel material with membrane separation technology. With a porous Type 316L stainless steel substrate sintered with a titanium dioxide (TiO_2) layer, the membrane surface is resistant to a wide range of chemicals, allowing for rigorous cleaning regimes to remove difficult foulants.

Because of its robust nature, FerroCep® is a versatile membrane that has been employed in many industries including food and beverage, textile, pulp and paper, oil and gas, metal and pharmaceutical. FerroCep® can help industrial users achieve significant cost savings through the reduction of production costs, energy consumption as well as wastewater discharge.

THE SUPERIOR INDUSTRIAL SEPARATION SOLUTION

TITANIUM DIOXIDE COATING LAYER

The inner surface of the FerroCep® tube is coated with a titanium dioxide (TiO_2) layer using a patented process which permanently bonds the TiO_2 particles onto the porous stainless steel substrate. This sintering process creates a smooth and foulant-resistant membrane surface with a nominal pore size of about 0.1 or 0.02 microns. The TiO_2 separation layer is listed as a Generally Recognised as Safe (GRAS) material under the United States Food and Drug Administration (FDA) and is suitable for food and drug applications.



Asymmetric membrane structure with enhanced flux performance

With the TiO_2 separation layer coated on its inner surface, FerroCep® possesses an asymmetric structure created by the gradual increase in pore size from the TiO_2 layer to the stainless steel substrate. As the permeate passes through the membrane tubes, it faces decreasing flow resistance as the pore size of each ensuing layer increases. Such an asymmetric structure lowers trans-membrane pressure (TMP), avoiding in-depth pore blockages and results in higher filtration flux rates.

THE SUPERIOR INDUSTRIAL SEPARATION SOLUTION

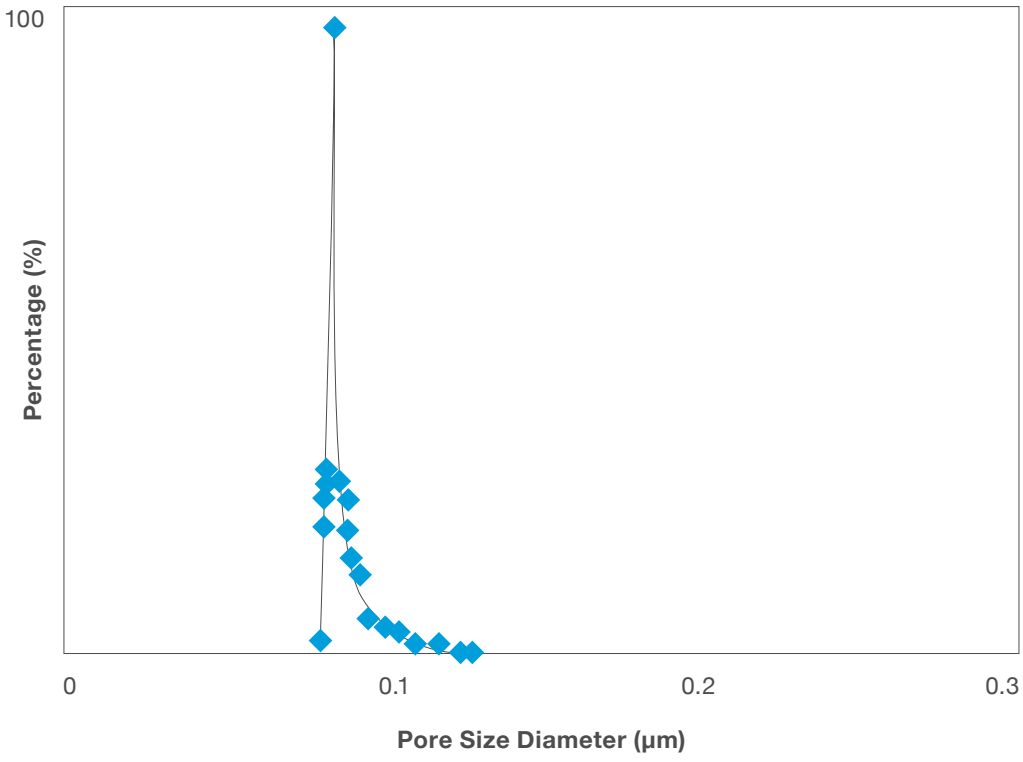
STAINLESS STEEL TUBULAR STRUCTURE

Exceptional mechanical strength and resistance to extreme conditions

FerroCep®'s ability to withstand extreme temperatures and pressures lies in the intrinsic properties of its austenitic porous Type 316L stainless steel material. The exceptional strength of the material enables the membrane tubes to withstand mechanical shocks. With its extra low carbon composition and non-magnetic property, FerroCep® is inert and is able to operate at a wide range of pH values with ease, avoiding unwanted chemical reactions while being exceptionally durable under extreme pressure and temperature of up to 315°C. FerroCep® can potentially be used for 10 years or longer, depending on the application environment.

SHARP PORE SIZE DISTRIBUTION

The sharp pore size distribution of the TiO_2 separation layer allows for precise filtration, rejecting particles that are larger than the nominal pore size, while allowing water and dissolved substances to pass through. This provides an effective separation barrier, whereby FerroCep® membranes can be used to remove impurities, or to concentrate industrial feed streams as the beneficial substances are retained at the surface of the membranes.

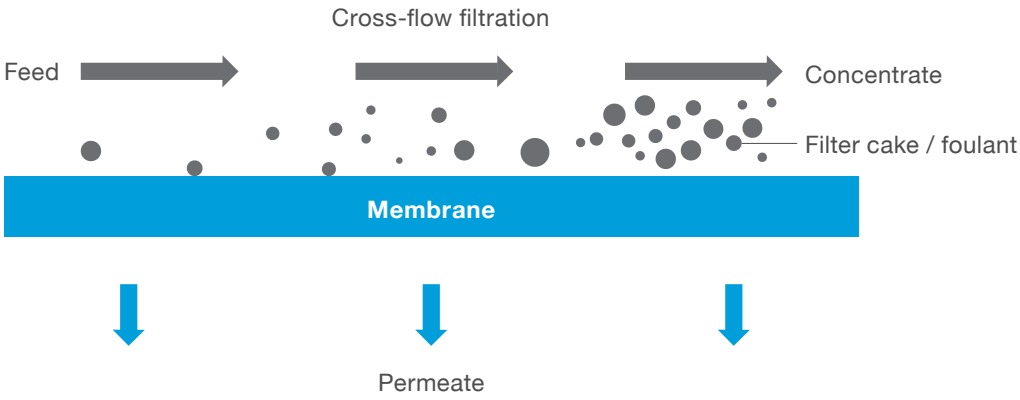


THE SUPERIOR INDUSTRIAL SEPARATION SOLUTION

WIDE MEMBRANE TUBE CHANNELS

Capable of handling high viscosity streams with minimal fouling

FerroCep® is fabricated in 18 mm channels that are much larger than typical inorganic tubular membranes. This enables FerroCep® to process extremely viscous process streams as well as complex mixtures with high solids content.



Operating under a cross-flow filtration scheme, FerroCep® is able to run at high cross-flow velocities that provide a “sweeping” effect to wash away any foulants residing on the membrane surface, while maintaining a reasonable TMP as compared to other membrane configurations with smaller diameters. FerroCep® can therefore be used for the processing of highly turbid fermentation broths, where suspended solids, bacteria, colloids and proteins are effectively removed to produce a permeate stream of high clarity.

REFERENCES

FerroCep® stainless steel tubular membranes have been used in many industrial applications worldwide and brought about significant benefits to its users. The table below shows a selection of projects where FerroCep® has been installed.

Applications	Country	Installed Membrane Area (m^2)	Completion/ Estimated Completion
Clarification /recovery of used engine oil	Vietnam	550	2015
Production of citric acid fluid	Thailand	1,000	2013
Production of erythromycin (phase 1 to 5)	China	10,000	2012
Production of soy bioactive peptides	China	98	2012
Clarification of purified terephthalic acid mother liquor	China	120	2011
Silica sol concentration	India	350	2010
Recovery of purified terephthalic acid mother liquor	China	480	2010
Production of cephalosporin C	China	480	2010
Production of clavulanic acid (phase 1 and 2)	China	1,065	2010
Clarification of amino acid fermentation	Indonesia	400	2009
Production of 1,3-propanediol	China	60	2008
Production of guanosine (phase 1 to 4)	China	480	2008
Production of food grade phospholipids	China	120	2008
Production of inosine	Japan	120	2007
Production of glutamic acid	China	120	2007
Production of glutamine	China	120	2006
Production of citric acid	Thailand	360	2003
Production of vitamin C	China	120	2003
Process Water treatment	Singapore	480	2001

CASE STUDIES

RECYCLING OF DEGREASING AGENTS IN STEEL INDUSTRIES

With the help of FerroCep®, the steel factory has been able to achieve significant savings as the life cycle of the degreasing solution is extended substantially. This decreases the daily amount of degreasing agent and water used and reduces wastewater produced.

Background
In the steel industry, large amounts of degreasing agents are required in degreasing solutions to wash off oil and grease from iron and steel surfaces. As oil and grease enters into the degreasing solution, an oil-water emulsion is formed. This reduces the solution's effectiveness by dissolving the degreasing agents, preventing them from coming into contact with the metal surface.

With increased usage, the emulsified oil content reaches 20 – 30 g/L eventually and renders the degreasing solution ineffective.

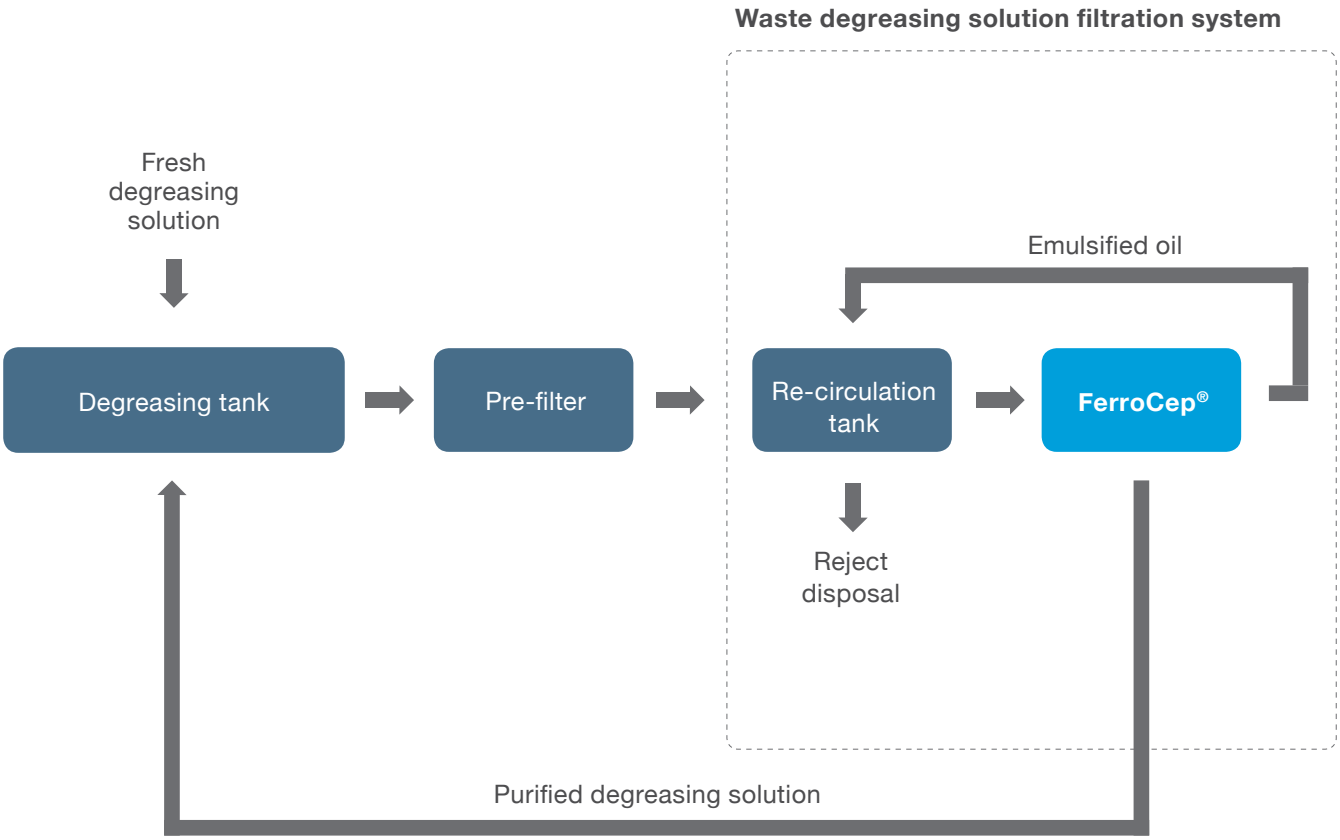
Solution
Hyflux's FerroCep® was selected to recycle alkaline-based degreasing agents and water in a steel factory. By separating emulsified oil, grease and sludge from the waste degreasing solution, the degreasing agents can be recycled.

The waste degreasing solution passes through a pre-filter to remove iron filings and other impurities before entering a recirculation tank. The solution is then pumped through FerroCep®, where separation of the emulsified oil and degreasing solution takes place. The emulsified oil is retained in the feed stream of the waste solution, while water and degreasing agents pass through the membranes. The purified degreasing solution is returned to the degreasing tank for reuse, and the process continues until the emulsified-oil concentration in the recirculation tank reaches a specified value, after which the concentrated wastewater is disposed.

This recycling system extends the life cycle of the degreasing solution substantially and reduces the usage of new degreasing agent and water every day. This translates to significant cost savings for the factory, with less wastewater produced.

CASE STUDIES

RECYCLING OF DEGREASING AGENTS IN STEEL INDUSTRIES



Process flow diagram for waste degreasing solution recycling system

CASE STUDIES

CLARIFICATION OF ERYTHROMYCIN FERMENTATION BROTH

The elimination of the flocculation and filtration conventional process results in immediate cost savings as no coagulants are required. The waste stream arising from the removal of impurities is easier to treat due to the absence of zinc and sulphate.

Background
A pharmaceutical company in China that produces the antibiotic erythromycin faced high production costs and low product quality.

The production process typically involves a stage where impurities such as mycelia, colloids and proteins have to be removed from the fermentation broth before further processing is done. Traditionally, zinc sulphate is added as a coagulant during the flocculation and filtration process to precipitate impurities. A filtration cake layer is then formed on the surface of the plate and frame filter to trap large particles, allowing smaller molecules such as erythromycin and other dissolved proteins to pass through.

However, the flocculation process consumes large amounts of zinc sulphate, leading to high production costs. The impurities contain high levels of zinc and sulphate which makes it very difficult to treat. Furthermore, a portion of the final product is removed during the flocculation step. The purity and quality of the final product is also compromised with high levels of proteins found in the product stream.

CASE STUDIES

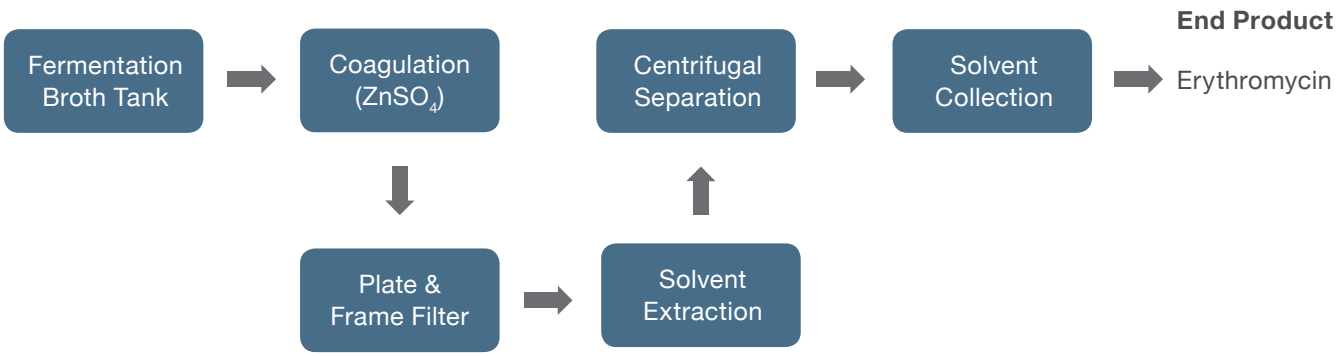
CLARIFICATION OF ERYTHROMYCIN FERMENTATION BROTH

Solution

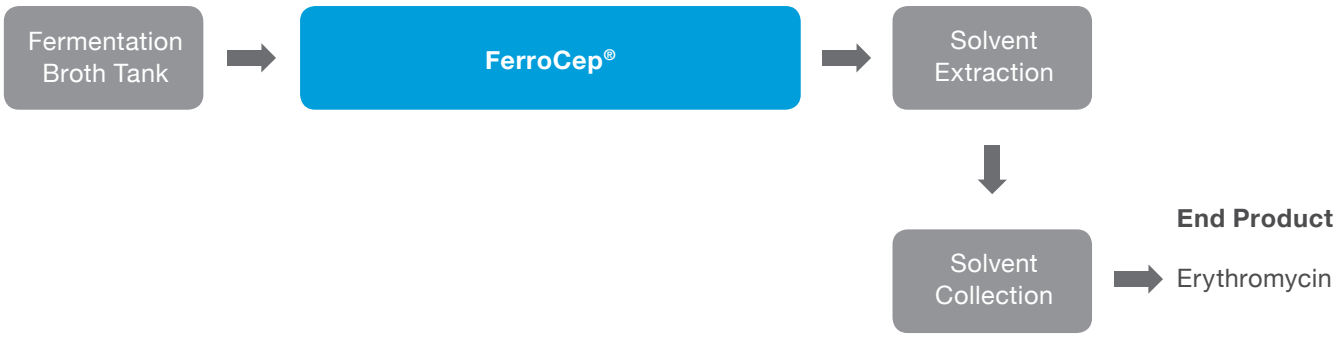
FerroCep® was chosen to replace the conventional treatment process which effectively eliminated the need for coagulants. FerroCep® with its membrane pore size of 0.1 micron is able to handle the high viscosity and solid content of the fermentation broth with its wide membrane channels and cross-flow operation. The tight pore size distribution of the membrane effectively removes impurities, thus producing a high quality filtrate for downstream processing.

By using FerroCep® the pharmaceutical company can produce erythromycin of a higher purity which commands a higher market selling price. In addition, the production yield has been increased by 3% to 5%. The elimination of the flocculation and filtration conventional process results in immediate cost savings as coagulants are no longer required. With the absence of zinc and sulphate, the resultant waste stream is easier to treat.

Traditional Process



FerroCep® Process



Process flow diagram for clarification of erythromycin fermentation broth

CASE STUDIES

PRODUCTION OF SOY ISOFLAVONES EXTRACT

FerroCep® eliminates the multi-step solvent extraction and vacuum concentration process which brings about significant cost savings in energy consumption and solvent use.

Background

Traditionally, producing soy isoflavones extract requires a complex process including ion-exchange, as well as a series of solvent extraction and vacuum concentration. This process unfortunately yields low quality products as vacuum concentration causes the darkening of the product and the presence of solvent residues leads to lower purity, which reduces the product's market price.

Large amounts of highly flammable solvents like methanol, ethanol and acetone are required in the process, which holds safety concerns. In addition, vacuum concentration also requires a lot of energy. The presence of polysaccharides, colloids, proteins and fibres cause fouling of the ion-exchange resins, and consequently low ion-exchange efficiency. The resins require constant replacement, resulting in product loss as the soy isoflavones cannot absorb onto the resins effectively. Overall, the process incurs high production costs due to the high consumption of energy and solvents.

Solution

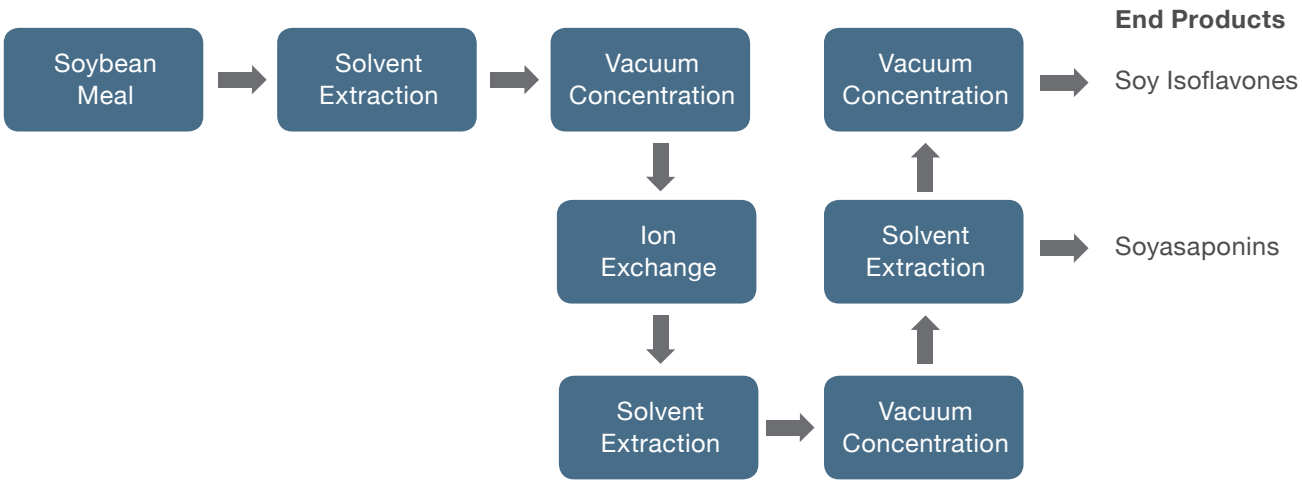
Hyflux's FerroCep® was selected to simplify the conventional process for a soybean processing plant in China. The wide channel membrane tubes are particularly suited for such applications as the feed stream is very viscous and contains high concentration of solids. FerroCep® eliminates the multi-step solvent extraction and vacuum concentration process, bringing about significant cost savings through a reduction in energy consumption and solvent use.

With FerroCep®, soy oligosaccharides and soy isoflavones passes through the membranes and are collected in the permeate stream, while impurities are filtered away in the concentrate stream. The downstream process of reverse chromatography separates soy oligosaccharides from soy isoflavones, to give a very high purity product. The concentrate stream undergoes further processing, to produce high value-added soy protein isolates, soy bioactive peptides and soyasaponins.

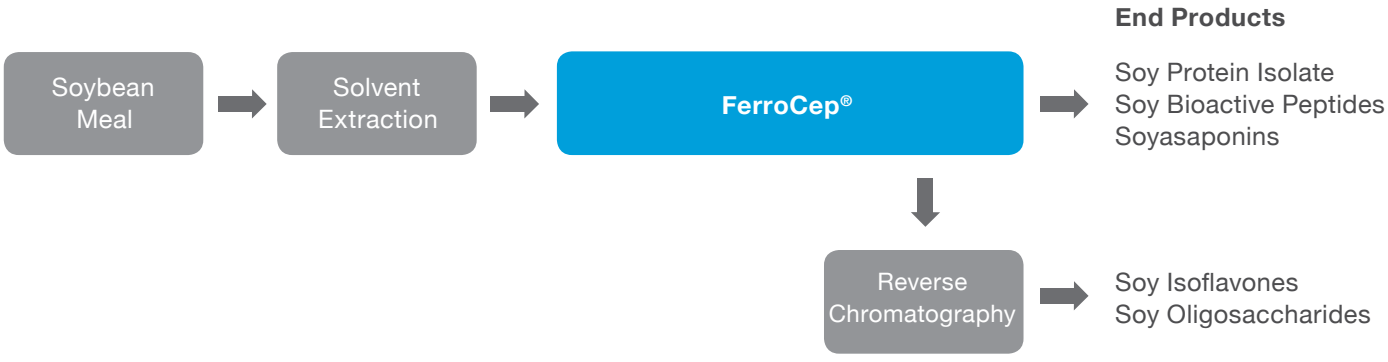
CASE STUDIES

PRODUCTION OF SOY ISOFLAVONES EXTRACT

Traditional Process



FerroCep® Process



Process flow diagram for production of soy isoflavones extract

02

TECHNICAL SPECIFICATIONS

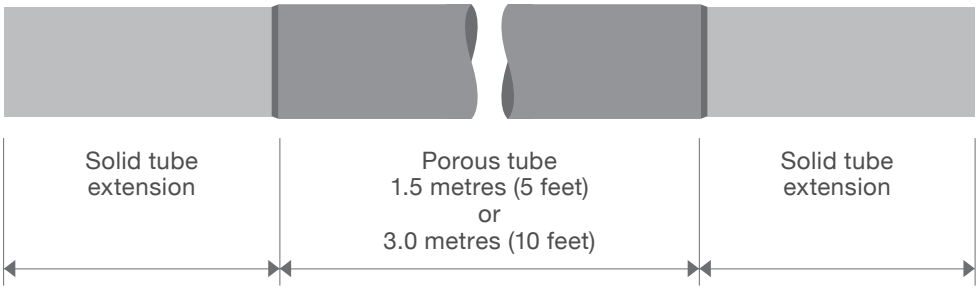
FERROCEP® SPECIFICATIONS

FerroCep® Membrane Specifications							
Pore size (µm)		0.1 / 0.02					
Tube length (nominal) (m)		1.5 / 3 / 6					
Outer diameter (mm)		21.5 ± 0.3					
Inner diameter (mm)		18.2 ± 0.2					
Tube material		316L stainless steel					
Coating material		TiO_2					
pH range		0 - 14					
Max. operating temperature (°C)		315					
Recommended operating pressure (bar)		4 - 6					
FerroCep® Module Specifications							
Model type		F2.5-A-0.3M	F4-A-2.4M	F6-A-5.4M	F14-A-60M	F20-A-121M	F26-A-202M
Nominal module length (m)		1.5	3		6		
Nominal pore size (µm)		0.1 / 0.02					
Tube per module (pc)		4	14	31	164	346	566
Clean water flux (m^3/module.hr @ 1 bar)	MF membrane	0.4	2.8	6.2	65.6	138.4	226.5
	UF membrane	0.1	0.9	2.1	22.6	47.7	78.1
Flow type		Inside-out					
Tube pass		1			2		
Feed connection (mm)		65	100	150	200	250	350
Permeate connection (mm)		25	38	50	50	100	150
Nominal module outer diameter (mm)		65	100	150	350	500	650
Permeate volume (L)		2.3	14	30	209	401	720
Concentrate volume (L)		1.5	11	25	250	528	864
Max. operating pressure (bar)		Up to 10.3*					
Max. operating temperature (°C)		Up to 140*					
Operating Parameters							
Operating mode		Cross-flow / dead-end					
Installation mode		Horizontal / vertical					
Flow configuration		Inside-out					
Max. operating pressure (bar)		10.3					
Max. TMP (bar)		10					
Service TMP (bar)		4 - 6					
Backwash pressure (bar)		1 - 6					
Operating temperature range (°C)		0 - 140					
Operating pH		0 - 14					
Cleaning pH		0 - 14					

* Subject to operating conditions and design requirements

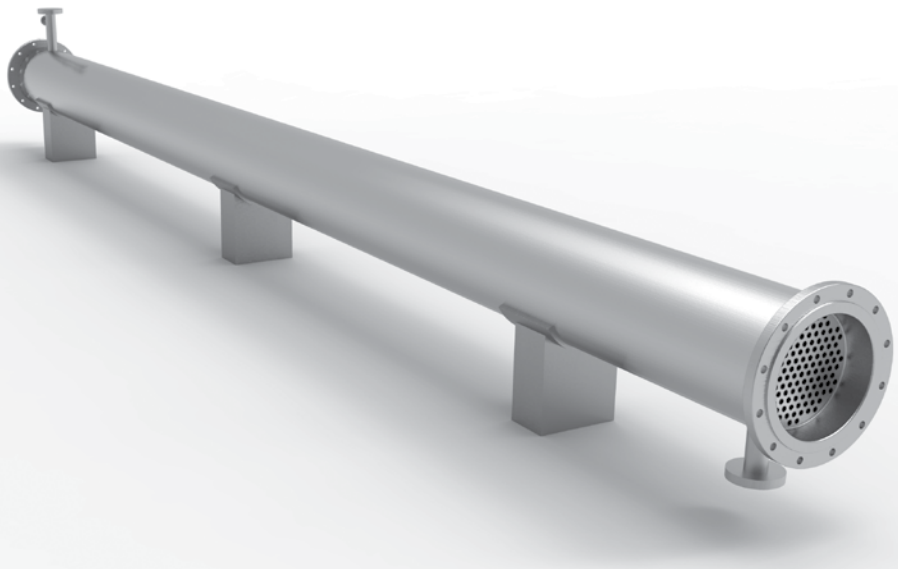
FERROCEP® MODULES

FerroCep® porous membrane tubes are fabricated in standard lengths of 600 mm, which are welded together to form standard tubes of 1.5 m or 3.0 m long. Solid Type 316L stainless steel tube extensions are then welded to the end of the porous tubes, forming tube assemblies which are subsequently fabricated into modules.



Standard FerroCep® tube assembly

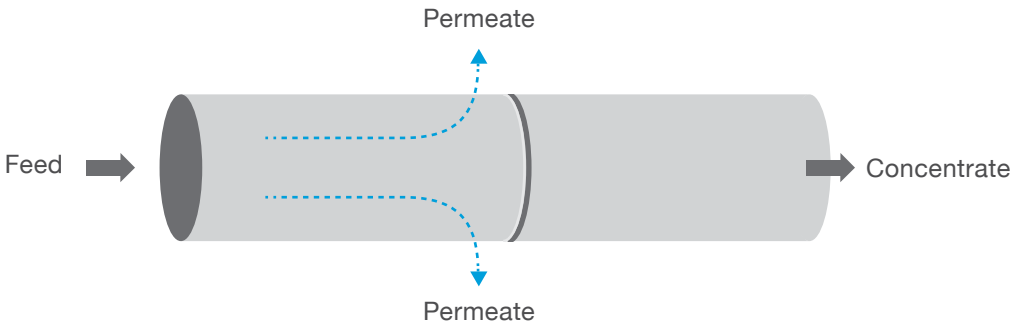
Each FerroCep® membrane module resembles a shell-and-tube heat exchanger, where the stainless steel membrane tubes are welded together with a stainless steel tubesheet. With a unique seamless fabrication, there are absolutely no leakages within the module.



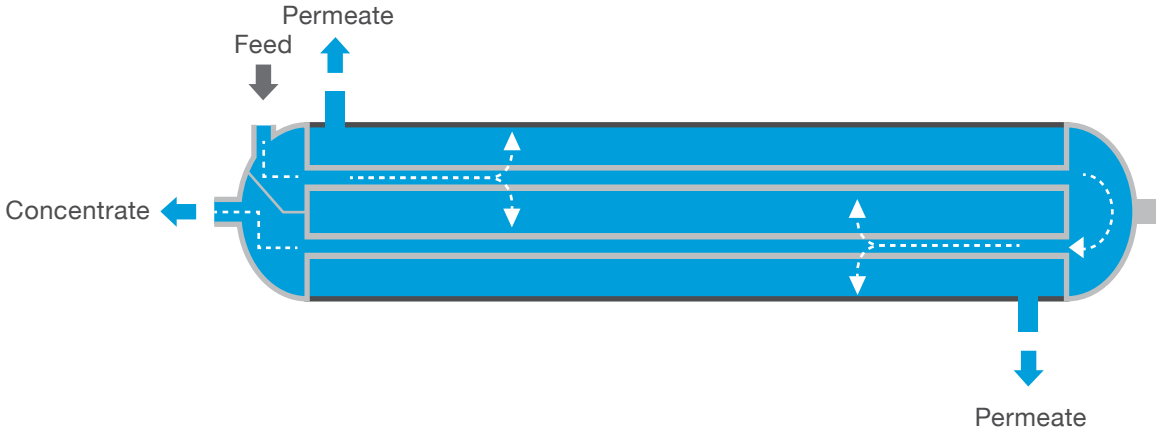
FERROCEP® FILTRATION PROCESS

The FerroCep® filtration process operates on an inside-out configuration, where the feed stream is circulated through the lumen of the membrane tubes. Solvents and dissolved substances pass through the cross section of the tube and are collected as permeate, with the concentrate being collected at the end of the tube.

FerroCep® modules are usually erected horizontally, although vertical installation is possible as well. For small modules of up to 5.4 m^2 membrane area, the module is designed for a single pass flow.



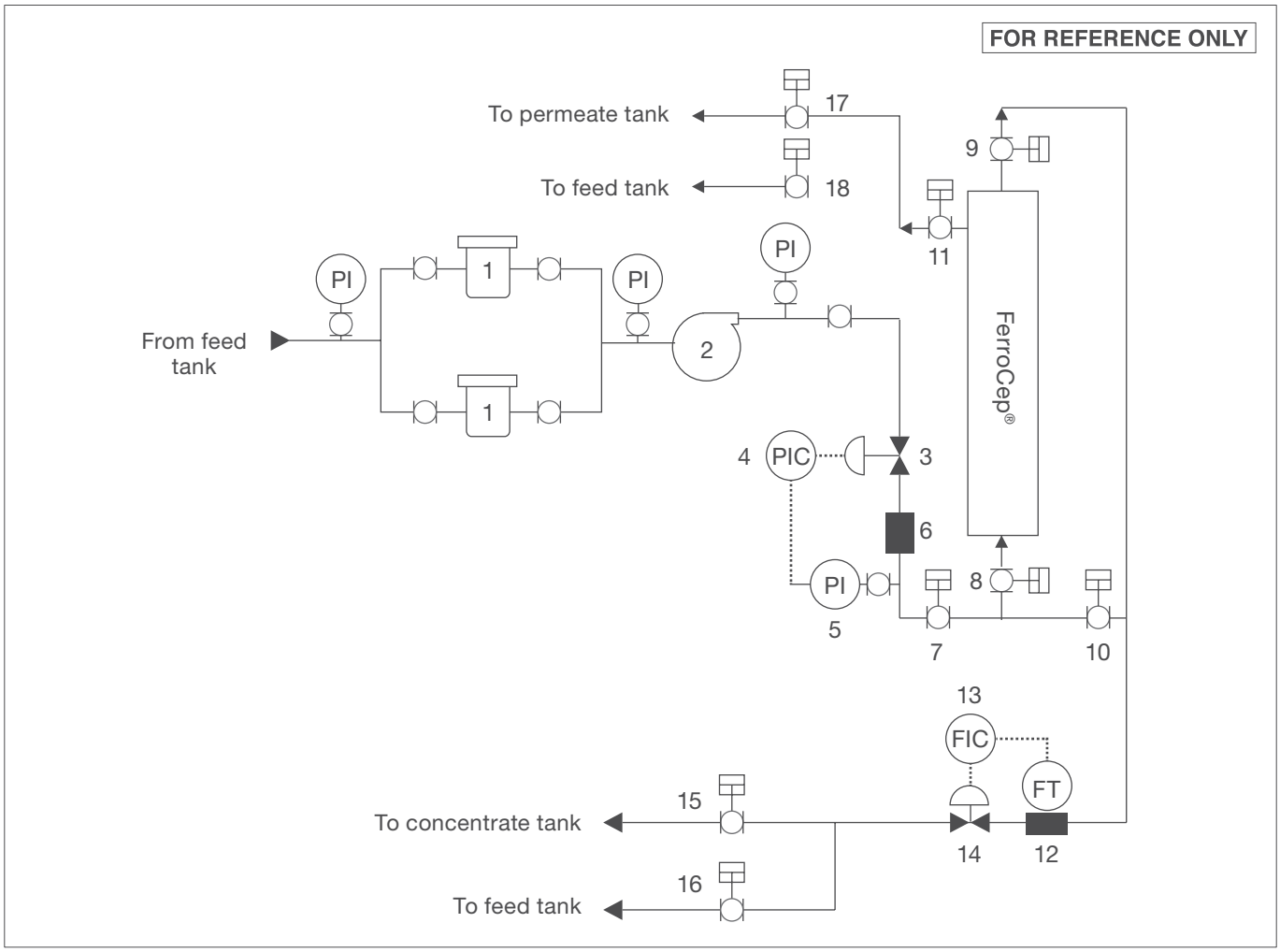
For larger modules of between 60 to 202 m^2 membrane area, the module is configured for two-pass flow, where the feed and concentrate streams are located on the same side of the membrane module. The feed stream passes from one end of the membrane module to the other, returning in the opposite direction through a separate set of membrane tubes before being collected as concentrate.



FERROCEP® CONFIGURATION

FerroCep® can be operated in various system configurations depending on the configurations of the particular application including batch, feed and bleed, single-stage, single-stage with re-circulation, and diafiltration.

The schematic below shows a typical FerroCep® set-up, which includes the necessary pre-filters, circulation pumps, instrumentation and control, with the flexibility of operating on different system configurations.



LEGEND

1. Feed pre-filters
2. Feed pump
3. Feed pressure control valve
4. Feed pressure controller
5. Feed pressure transmitter
6. Feed flow transmitter
7. Feed shut-off valve
8. Feed valve
9. Concentrate valve
10. By-pass valve
11. Permeate valve
12. Concentrate flow transmitter
13. Concentrate flow controller
14. Concentrate flow control valve
15. Concentrate tank valve
16. Concentrate recycle valve
17. Permeate tank valve
18. Permeate recycle valve

ABOUT HYFLUX

At the core of Hyflux's business is its membrane innovation that is focused on the development of membranes, membrane applications, and the design and development of membrane-based plants to deliver solutions for a wide range of applications in water treatment and industrial manufacturing processes.

Hyflux is a leading fully-integrated provider of water and power management and innovative environmental solutions. Hyflux offers sustainable solutions in the areas of membrane-based desalination, water recycling, wastewater treatment including membrane bioreactor technology, and potable water treatment. Its projects and operations span across the globe and include landmark projects such as some of the world's largest seawater reverse osmosis (SWRO) desalination plants in Singapore, Algeria and China.

Hyflux is distinctive in its ability to address the challenges at every point of the entire value chain of the water industry – from R&D in membrane technology, component manufacturing, process engineering, engineering, procurement and construction (EPC), to operations and maintenance (O&M), in addition to arranging for project financing of large-scale municipal water projects.

At the core of Hyflux's business is its membrane innovation that is focused on the development of membranes, membrane applications, and the design and development of membrane-based plants to deliver solutions for a wide range of applications in water treatment and industrial manufacturing processes. Today, Hyflux's membrane systems have been installed in more than 1,300 plants in over 400 locations worldwide.

Through its projects across the world, Hyflux has left an indelible imprint on the communities that it serves, driven by its commitment to deliver water that is clean, safe and affordable.

HEADQUARTERS

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