Press Release

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Trend Report No. 11: Chinese Water Industry

Chinese water industry booming – rising demand by industry and municipalities

- **Membrane technologies – the key to innovations in the water sector**
- **Upgrading of existing facilities a necessity**
- **AchemAsia – a forum for international exchange of ideas and experience**

The responsible use of water is the basis for sustainable global development and stable economic growth. The need for enhanced production process efficiency and advanced product quality standards requires innovative, optimized water treatment technologies. Their integration is a challenge to process engineering.

AchemAsia 2007 from 14 – 18 May in Beijing, VR China, is the leading international event for equipment suppliers of the process industry. As such it will once again spark off trend-setting impulses for technology developments and new business networks in the sector of water technologies, too. The event is expected to attract some 500 exhibitors and 20,000 visitors from all over the world.

Overtaxed by population growth and increasing industrial demand, supplies of fresh water are becoming scarcer and more expensive throughout the world. At the same time operation of chemical process plants is subject to ever-stricter regulations on the discharge of effluents. The result is an increasingly pivotal role for novel wastewater treatment technologies.

Wastewater treatment in industry varies widely from plant to plant, even for those that make similar products. However, the basic, common elements are typically the separation of valuable chemicals that are recycled to the process and of hazardous materials that cannot be discharged, followed by treatment of the resultant aqueous waste stream to meet discharge requirements. Methods used include mechanical filtration and separation, chemical and biological treatment, clarification, flotation, and evaporation.

Chinese water industry booming – rising demand by industry and municipalities

With an annual growth rate of around 15% the Chinese market for water treatment is second only to the USA. Moreover this development is given added impetus by the 2008 Olympic Games in Beijing and Expo 2010 in Shanghai.

In China wastewater treatment continues to be a problem. Statistics indicate that China's wastewater treatment rate is currently about 50 %. There is a lack of adequate sewage

collection systems and existing systems frequently fail to function satisfactorily. According to data from the China Sewage Treatment Industry Report 2006 (www.researchandmarkets.com/reports), 278 of China's 600 historical grown cities do not have any, or do not have sufficient, wastewater treatment facilities. The goals set in the 11th Five-Year Plan (2006-2010) envisage an investment of 330 billion RMB for this sector. This is also a promising market for foreign companies. To date the share of foreign capital is less than 10%.

Siemens is one of the global players on the Chinese water market, particularly for industrial water treatment. With its recent acquisition of 70% of CNC Water Technology Inc., Beijing, a successful Chinese system integrator of water treatment and seawater desalination plants, Siemens is expanding its industrial water treatment business in China, the bias being on filtration applications. Founded in 2002, CNC was the first company on the Chinese market to use membrane filtration in water treatment and seawater desalination. CNC has successfully carried out a number of the biggest Chinese projects for seawater desalination and for industrial and municipal water treatment and covers sectors, such as petrochemistry, refineries, steel and energy production.

Germany is the world's leading exporter in the area of plant, components and systems for industrial water and wastewater treatment. According to data from VDMA, in 2005 Germany's exports in this sector rose by around 30%. Germany's share of 564 million euros (20.2%) catapulted her to the top of the league, followed by the USA with 557 million euros and France with 200 million euros. In the first half-year of 2006 Germany's production volume again increased by 8%, and the branch anticipates a new production record of 675 million euros for the whole of that year.

Advances in membrane technology

Since most plants already have many of these elements in place, the further cleanup of water for recycling is most likely to involve advanced treatment processes, e.g. the addition of microfiltration (MF) or ultrafiltration (UF) membranes, followed by nanofiltration (NF) or/and reverse osmosis (RO) at the end of the treatment process. Companies that require water of higher purity, such as pharmaceutical and semiconductor operations, may add ion exchange or electrodeionisation. On average, RO will remove – depending on the kind of molecules – between 90 % and 98 % of the dissolved solids, but ion exchange or electrodeionisation will reduce the dissolved solids content to a couple of ppm or less.

Using membranes for recycling water is particularly attractive if water reuse is accompanied by recycling of product or other resources. In cases where water scarcity does not play a major role, product recycling is the decisive factor. Enviro-Chemie GmbH has implemented Envopur® recycling units for water and product in a range of different industries, including the textile industry, dye production, production of basic chemicals, manufacturing of glassware and ceramics. Often membrane technology is accompanied by other physico-chemical processes like ion-exchange, adsorption and precipitation processes.

One of Mexico's largest oil refineries, Pemex, chose a ZeeWeed® UF membrane system from Zenon for it's Minatitlán wastewater reclamation plant. This treatment technology is capable of providing high quality effluent for reuse as cooling tower make up and for refining purposes.

The potential of membranes for water desalination is creating a market that is robust and growing rapidly. Because the main process component, the membrane, is structurally a commodity product, the market is extremely competitive. That state of affairs is expected to continue as membrane performance is improved and costs are reduced, giving users greater flexibility to change products and vendors.

The competition is fierce. As an indication of the growing demand, Koch Membrane Systems, Inc. reports that the interest in UF and RO for new projects has increased dramatically. Five years ago, about 10 % of its pilot studies were for UF/RO; today, 90 % of its pilot work is for the evaluation of UF/RO to recycle water and eliminate discharge to publicly owned treatment plants.

General Electric Infrastructure, a relative newcomer to water treatment, decided to enter the market about three years ago after an extensive study showed a huge potential for water-recycling. Since then, GE has made a number of acquisitions, including water-treatment company Betz Dearborn, Osmonics, which makes spiral-wound membranes, and Ionics, Inc., which has expertise in the construction of very large desalination plants.

Other multinationals with a vested interest in power generation are fortifying their operations by strengthening their capabilities to treat supply process water. In 2004, Siemens AG acquired USFilter. In the past five years USFilter's Memcor, Microfloc and General Filter Products operations have installed more than a dozen large-scale membrane systems in industrial plants to recycle, versus only a handful in the previous decade. The company has also installed more than 40 smaller-scale units for such businesses as printed-circuit-board manufacturing and metal-plating operations.

Also in 2004, ITT Industries, which serves the power industry with pumps, valves and other systems, formed Aquious-PCI Memtech. The new unit is a consolidation of the company's existing and acquired membrane filtration products. With projects underway, that include the supply of drinking and process water in the Middle East, Aquious expects to reinforce its position as a major player in membrane desalination.

Beside these companies Ondeo Industrial Solutions Hager + Elsässer, subsidiary of SUEZ, Linde-KCA-Dresden GmbH, a subsidiary of Linde AG, Veolia Water (formerly Vivendi SA), Gromtmij, DHV Water, and Membrana GmbH offer their solutions on this growing market.

Not only is the use of membrane technology for desalination or for recycling strategies increasing rapidly, but also end-of-pipe applications based on membranes are being increasingly applied to reduce emissions and save resources. One example of the first target is the decontamination of radioactive contamination effluent from a biological treatment plant with crossflow-microfiltration installed by WAT-membratec. Both targets are achieved by a plant installed by the same company for the recovery of valuable substances in the chemical industry. Here the residual liquid after completion of a batch is completely discharged from the whole system by pneumatic flushing. This dramatically reduces the need for flushing and cleaning liquids and boosts the yield of the process significantly. The use of polypropylene membranes permits operation in the whole pH range.

It is obvious that the increasing costs of water and wastewater in industrial applications are currently the driving forces behind the installation of membrane plants in many different areas where this technology was formerly not accepted as a solution. This was the case in industries with process water or wastewater containing abrasive particles, such as from glass processing, high pressure cleaning or grinding. Solutions are offered by UFI-TEC, for example microfiltration is used for the treatment and recycling of abrasive wastewater from wet screening of corundum in a plant with 10 m^3/h. The results are: decreasing fresh water and wastewater costs, improved the product quality using optimum process water and compliance with effluent discharge conditions.

Similar technology from UFI-TEC can be installed as one step of a multi-stage process for the purification of pig slurry that starts with the separation of undissolved solids and ends with the separation of all kinds of dissolved solids using reverse osmosis as the last step. The products are clean water and fertilizer of different conditions and quality. The same concept is the basis for the treatment of fermentation broth resulting during the production of biogas from biomass of agricultural provenance offered by WAT-membratec. In both applications membrane processes help to convert the discharge of liquids with increasing negative impact on the environment into the recovery and reuse of valuable substances.

Advances in membrane technology in the field of seawater desalination also include innovative pumps and special energy saving devices which are starting to supersede the well known energy recovery units. Combining an adequate feed pump with a booster pump and a pressure exchanger, Grundfos offers the modularised system BMEX that helps to reduce the energy demand to between 2.2 and 3.0 kWh/m^3 of permeate, depending on the size of the plant and the quality of the seawater. New is the possibility to use this technology in the wide

range from very small units with a permeate production of a few m³/h up to big plants with a few hundred m³/h.

Another innovation related to membrane technology and seawater desalination is the NMU process for seawater intake and pre-treatment offered by Auqa-Society and partners. NMU combines directed drilled horizontal drains in the sand layer below the seabed, acting as pre-filters, with micro-bubble flotation and ultrafiltration in front of the reverse osmosis modules. This allows to minimize or even avoid the dosing of chemicals that are necessary in conventional open seawater intake systems.

Ultrapure water

Another budding use for membranes is in the production of ultrapure water (UPW) systems. At a major semiconductor fabricator in China, for instance, Liqui-Cel® Membrane Contactors from Membrana are used to remove dissolved oxygen to less than 1 part per billion (ppb). Specifically to the semiconductor market, high levels of O_2 can cause lower wafer yields. Membrane contactors have become the standard for oxygen removal as well as CO_2 removal in high-purity and industrial applications. Larger contactor sizes with greater membrane surface areas have made the membrane contactors even more economical as flow rates have increased and the gas outlet specifications have become tighter. UPW systems also provide the contaminant-free water used in human injectables, supercritical coal-fired boiler steam systems, and in chip cleaning in the semiconductor industry, which are other focus areas for Christ Water Systems.

This technology is also used for the production of UPW, for example boiler feed water, from WAT-membratec, which offers a complete range of project stages from the first layout proposal, followed by piloting, planning, manufacturing, automatization and commissioning, up to maintenance with their own highly qualified personnel. The membrane contactor is installed between the reverse osmosis and the electrodeionisation stage, reducing CO_2 to less than 1 mg/L and O_2 to less than 0.02 mg/L. Similar systems from this plant manufacturer are operating in semiconductor applications or dialysis stations.

According to the latest forecasts from the McIlvaine Co. (www.mcilvainecompany.com) the worldwide market for UPW systems will reach US$ 4 billion by 2009. The largest segment of these is the semiconductor industry, where UPW systems sales are expected to exceed US$ 1.7 billion in 2009. Much of the growth will come from Tiawan, Japan, South Korea and China. In the pharmaceutical sector the sales volume of ultrapure water systems is set to rise continually by 8%, by 2009 it will exceed the US$ 300 m threshold. In this sector biotechnology is growing at a considerably faster rate than the total market for pharmaceutical ultrapure water systems.

Meanwhile, there is a big transition in the power segment where sales of UPW systems for coal-fired boilers are rapidly increasing. The latest supercritical coal-fired boilers deliver higher efficiency and lower greenhouse gas emissions. But with the high temperatures and pressures, the water purity requirements are greater than with subcritical boilers.

UPW systems purchases for coal-fired boilers are expected to exceed US$ 1 billion in 2009. This compares to only US$ 50 million that is projected for UPW spending related to gas turbines.

UPW systems are highly instrumented. Therefore, 2009 purchases of instruments and controls for UPW systems may exceed US$ 500 million. Meanwhile, purchases of membranes and membrane systems may reach US$ 600 million, and pump and valve purchases are likely to exceed US$ 250 million. Significant purchases will be made for degasification, disinfection, ion exchange, storage, and piping.

The design and erection of UPW treatment plants for the semiconductor industry is a very highly sophisticated business regarding the increasing quality demands of semiconductor industry. Less companies in the world are able to build UPW treatment plants which are able to fulfill the latest UPW specifications. One of them is Ondeo Hager + Elsässer.

Improvements in membranes

Improvements in membranes, to reduce energy consumption and obtain better rejection of dissolved solids, have been achieved in incremental steps over the years. New spiral-wound RO membranes from Dow subsidiary FilmTech Corp., a subsidiary of Dow Chemical Company, can operate below 100 psi for brackish water, compared to 100-150 psi about five years ago.

Dow's latest innovation is a new method of interconnecting spiral-wound membrane modules, which connects groups of six or eight in series within a pressure vessel. Ordinarily, the modules are connected by plastic pipe with O-rings, but the seals tend to get rolled or pinched, resulting in leaks. Dow's innovation, an interlocking end cap, is an axial compression seal that is said to eliminate this problem.

Koch has a new spiral-wound membrane module that was developed to reduce costs. Called MegaMagnum, it measures 18 in. dia by 61 in. long, versus 8 by 40 in. for standard modules. The benefits, says the company, are lower installation time, lower labor cost and reduced seal and piping complexity; furthermore, the unit takes up only one-third to one-half the floorspace of conventional membranes. On installations made so far, the capital savings have been as much as 14 %, compared with standard modules.

Pall Corp., whose divisions include the U.K.-based USF Seitz Schenk Filtersystems, is cruising in the water desalination market with its Marine Disc Tube. The unit consists of a chamber of discs interleaved with flat membrane cushions held in a tubular chamber. Seawater under pressure flows up and over each membrane cushion, allowing water to pass through a semipermeable membrane, and is collected as a clean water stream. Self cleaning, the membrane has a service life of five years or more. When in need of replacement, individual membranes, rather than complete modules, can be exchanged.

While RO has been used for decades in municipal water-treatment plants and to produce potable water from seawater and brackish water, treating plant waste streams presents some special challenges. Where municipal wastewater is well understood and does not vary much, for an industrial waste stream a pilot plant is necessary to prove that the system works and that the membranes will stand up.

Common materials used in membranes are polyacrylonitrile (PAN) and polyvinylidene fluoride (PVDF), which are popular choices for oily waste streams; and polysulfone, which is not suitable for hydrocarbons. (For a fuller list of membrane materials, see the table below). RO membranes are typically composites. And, while PVDF is resistant to such oxidants as chlorine, there are some aromatic solvents that could dissolve it. In such cases, probably the best course is the removal of the solvents upstream from the membrane.

Membrane filter types and characteristics			
Material	Abbr.	Advantages	Disadvantages
Polypropylene	PP	Low cost High pH range tolerance	No chlorine tolerance Expensive cleaning chemicals required
Polyvinylidene fluoride	PVDF	High chlorine tolerance Simple cleaning chemicals	Cannot sustain pH > 10
Polyether sulfone & polysulfone	PES/PS	Chlorine tolerance Reasonable cost	Brittle material requires support or flow inside to outside
Polyacrylonitrile	PAN	Low cost typically used for UF membranes	Less chemically resistant than PVDF
Cellulose acetate	CA	Low cost	Narrow pH range Biologically active

GE has recently introduced some new membranes that can tolerate pH conditions below 2 and above 12, whereas conventional membranes are limited to pH levels of around 4 and 10.

Also new from GE are membranes that can operate up to 90 °C, versus about 60 °C for standard membranes. The higher temperature allows water to be recovered from hot condensate, so that it does not have to be reheated for boiler or process use.

The USFilter unit of Siemens Water Technologies offers a membrane bioreactor, the MemJet MBR Express, that combines activated sludge and microfiltration membranes in one package. The bioreactor is a tank that has an inlet for wastewater at the front end and hollow-fiber membranes at the outlet end. As the wastewater flows through the tank, air is injected to promote biological activity. Air is also injected through the membranes, serving the dual purpose of preventing membrane fouling and adding oxygen to the process.

Solids rejected by the membranes are recycled to the tank inlet. This allows the solids concentration to be maintained between 10,000 and 15,000 mg/L, versus 3,000 to 5,000 mg/L for a conventional activated sludge process. The bacteria work much more efficiently at the higher solids concentration. Traditionally, most of the initial installations have taken place in municipal treatment plants, but more recent installations have turned up in petroleum refineries and petrochemical and steel plants.

In 2005, USFilter announced the development of a new square membrane module for its Memcore membrane bioreactor systems. The new robust square module incorporates an enhanced fiber technology in an optimal configuration, which results in reduced capital and operating costs and simplified wastewater-treatment design and installation.

Among strong activities in the MBR section, Microdyn-Nadir GmbH, which has delivered flat sheet membranes for submerged modules in that application for years, has now developed its own submerged module for MBR. Based on long-term experience with membranes the company has now entered the market with the Bio-Cel® module. This module is the first module based on flat sheet membranes which are back flushable as hollow fibre membranes. Instead of a plate which is normally needed to fix the membrane, Microdyn-Nadir uses a self-supporting thin layer which enables to reach package densities like hollow fibre modules. Furthermore the design has been optimised to avoid braiding and sludge deposition in the modules. The modules can be operated long-term at a stable flux and require little cleaning.

Water technology at the AchemAsia Exhibition & Congress 2007

Numerous exhibitors and contributors to the congress program will pinpoint the latest trends and technologies in the area of water and wastewater treatment technologies for industrial application. The themes span the whole range from the reduction of process water by innovative process techniques to the most diverse water recycling processes. The key topics of the congress are: sustainable water management for industries and municipalities, biological wastewater treatment, advanced oxidation technologies, membrane technologies, and water resources for industrial processes.

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