CHRONICLING PROCESS INDUSTRY INNOVATIONS SINCE 1966

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CHEMICAL ENGINEERING WORLD
RNI REGISTRATION NO. 11403/1966

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Single Copy Price: ₹ 150/-,
Annual Subscription: ₹ 1620/-, Foreign: USD 180

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PLACE OF PUBLICATION
JASUBHAI MEDIA PVT. LTD.

210, Taj Building, 3rd Floor, Dr. D. N. Road, Fort,
Mumbai 400 001, Tel: +91-22-4037 3636

Printed and published by Mr Hemant K. Shetty
Address: 406-D, The Karachi Citizens Co-Op Hosg Soc Ltd.,
Juhu Varsova Link Road, Andheri West, Mumbai - 400053.

Printed at The Great Art Printers
25, Unique House, S A Brelvi Road, Fort, Mumbai 400 001.

Editor: Ms. Mittravinda Ranjan, 3rd Floor, Taj Building, 210,
Dr. D N Road, Fort, Mumbai 400 001.

Published from Jasubhai Media Pvt .Ltd. 3rd Floor, Taj Building,
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L&T Delivers World's Heaviest EO Reactors to China

Mumbai, India: Larsen & Toubro (L&T) has successfully dispatched two of the world's heaviest Ethylene Oxide (EO) Reactors to BASF's petrochemical project in Zhanjiang, China. Weighing 1,136 MT each, these reactors were built at L&T's A M Naik Heavy Engineering Complex in Hazira, Gujarat. These EO Reactors, essential for the catalytic conversion of ethylene into ethylene oxide, represent a significant engineering achievement. Manufactured using advanced Industry 4.0 technology and world-class quality processes, they mark the heaviest reactors ever produced in BASF's nearly 160-year history.

Mr. Anil V Parab, Whole-time Director & Sr. Executive Vice President, L&T Heavy Engineering & L&T Valves, expressed pride in the accomplishment, thanking BASF for the opportunity and highlighting L&T's commitment to reliability and customer satisfaction despite global supply chain challenges. BASF's Senior Vice President, Joachim Thiel, lauded the reactors as critical for their Verbund project and praised the collaborative effort between BASF and L&T. Dr. Joachim Queisser, Senior Vice President, Global Technology, Safety & Quality, Petrochemicals at BASF, commended L&T's craftsmanship and competence, underscoring the partnership's success. This milestone underscores L&T's global engineering capabilities and stands as a testament to the "Make in India" initiative, showcasing India's prowess in high-end manufacturing on the world stage.

DCM Shriram Partners with ICT Mumbai for Advanced Chemical R&D

Mumbai, India: DCM Shriram, a leading chlor-alkali manufacturer, has signed a Memorandum of Understanding (MoU) with the Institute of Chemical Technology (ICT), Mumbai, to enhance research and development in the chemical industry. This strategic collaboration aims to leverage ICT Mumbai's academic strengths alongside DCM Shriram's industrial expertise. The MoU was signed during a formal ceremony attended by Prof. Aniruddha Pandit, Vice Chancellor of ICT Mumbai, and Dr. Debabrata Rautaray, Chief Product Development & Innovation Officer at DCM Shriram Chemicals.

Mr. Sabaleel Nandy, Executive Director & CEO of DCM Shriram Chemicals, stated, "Partnering with ICT Mumbai aligns with our commitment to pioneering cutting-edge solutions and enhancing our product development capabilities. We are confident this synergy will yield significant advancements towards delivering sustainable solutions to our customers." The collaboration will focus on specialized R&D projects in chemical engineering and processing, epoxy polymers and composites, water treatment chemicals, and bio & sustainable materials. ICT Mumbai will conduct these projects under the guidance of designated experts, while DCM Shriram will ensure alignment of project goals and practical application of research outcomes. Prof. Pandit expressed his enthusiasm, noting the mutual benefits of the partnership and its potential to offer ICT students future career opportunities with DCM Shriram.

Aarti Industries Appoints Suyog Kalyanji Kotecha as CEO

Aarti Industries has appointed **Suyog Kalyanji Kotecha** as its new Chief Executive Officer (CEO), succeeding Rajendra V Gogri who will continue as Chairman and Managing Director. Kotecha, holding degrees in Chemical Engineering and Management, brings extensive experience from roles including Strategy and New Business at Reliance Industries and as a Partner at McKinsey & Company. Gogri emphasized Kotecha's expertise in specialty chemicals and strategic growth, highlighting his global industry connections and commitment to sustainability. The appointment aims to steer Aarti Industries through its next phase of growth and innovation in the chemicals sector.

Aarti Industries and UPL Form JV for Specialty Chemicals Manufacturing

Mumbai, India: Aarti Industries Ltd. (AIL) and UPL, both leading firms in specialty and agrochemicals, have entered into a 50:50 joint venture (JV) partnership to manufacture and market specialty chemicals. The JV, named Augene Chemicals, will focus on producing downstream derivatives of amines used in agrochemicals and paint industries. Combining their strengths, AIL and UPL will supply essential raw materials for the manufacturing process. Commercial operations are slated to begin in Q1 FY 2026-27, with the JV targeting an annual revenue of ₹400-500 crores within 2-3 years. This partnership marks a pioneering collaboration between two major Indian companies to develop and market value-added chemical intermediates for global markets. AIL and UPL have built this venture on a longstanding relationship of over two decades.

Mr. Rajendra Gogri, Chairman & Managing Director of AIL, described the partnership as a groundbreaking development that leverages the synergies of both companies to support the manufacturing of critical chemical products in India. He emphasized that this collaboration demonstrates India's capability to create world-class chemical manufacturing assets through strategic partnerships. Mr. Raj Tiwari, CEO of UPL Specialty Chemical Business, highlighted that this JV aligns with UPL's strategy of expanding into newer chemistries to drive the growth of their specialty chemicals platform.

Brenntag Expands Material Science Innovation & Application Center

Mumbai, India: Brenntag, the global leader in chemicals and ingredients distribution, has announced the expansion of its Material Science Innovation & Application Center in Navi Mumbai. This state-of-the-art facility aims to advance Brenntag's work in powder coatings, adhesive applications, and enhanced water-based and solvent-based coatings. The expanded center features new laboratories equipped with advanced testing equipment, enabling researchers to accelerate the development of innovative coating formulations. Emphasizing sustainability, the facility will prioritize eco-friendly materials to reduce environmental impact while maintaining high performance.

Designed to foster innovation and teamwork, the center includes collaborative spaces for scientists, engineers, and industry partners. As part of Brenntag's global network of Material Science Innovation & Application Centers, the Navi Mumbai facility will share expertise and best practices worldwide. The expansion is also set to create new job opportunities, attracting top talent in material science, chemistry, and engineering, thereby strengthening Brenntag's industry leadership and contributing to local economic growth. Sanjay Karkhanis, President CASE, Material Science, Brenntag Specialties, stated, "The expansion of our Material Science Innovation & Application Center underscores our dedication to pushing the boundaries of material science. By investing in advanced research capabilities, we are poised to deliver cutting-edge solutions that address the challenges of today and tomorrow."

PESB Recommends Ajay Kumar Sharma, Director (Personnel), SJVN

The Public Enterprises Selection Board (PESB) has recommended **Ajay Kumar Sharma as SJVN Limited's new Director (Personnel),** following a competitive selection process. Currently serving as General Manager in the Corporate Human Resources department at SJVN, Sharma joined the company in October 2009 and has played a pivotal role at the Corporate Headquarters in Shimla. His expertise spans personnel planning, administration, industrial relations, HR policy, training, development, and procurement. Sharma has been instrumental in supporting the Director (Personnel) and the Chairperson & Managing Director of SJVN, underscoring his suitability for the elevated role in the prominent PSU under the Ministry of Power.

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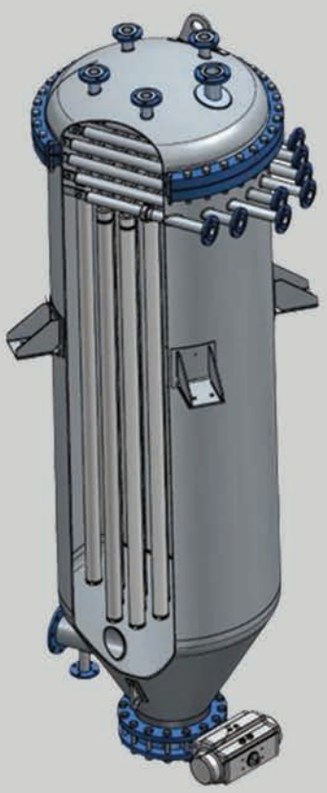

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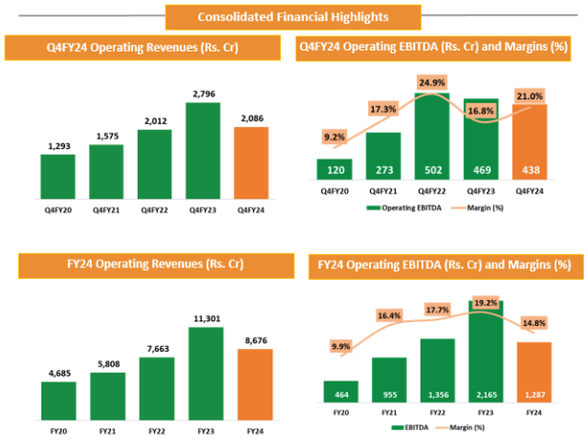
BHEL Partners with BARC for Hydrogen Production Technology Transfer

L-R Mr. Jai Prakash Srivastava, Director (Engineering, Research & Development), BHEL by Mr. K. Ravishankar, Executive Director (Corporate Technology Management and Corp R&D), BHEL and Dr. S. Adhikari, Associate Director (Knowledge Management Group), BARC

New Delhi, India: Bharat Heavy Electricals Limited (BHEL) has signed a Technology Transfer Agreement (TTA) with Bhabha Atomic Research Centre (BARC) for 50 kW alkaline electrolyser systems to produce hydrogen. The technology, developed indigenously by BARC, features a high local material content. The agreement was signed by Mr. K. Ravishankar, Executive Director (Corporate Technology Management and Corporate R&D) of BHEL, and Dr. S. Adhikari, Associate Director (Knowledge Management Group) of BARC, in the presence of Mr. Jai Prakash Srivastava, Director (Engineering, Research & Development) of BHEL.

Through this collaboration, BHEL aims to scale up the Indigenous Alkaline Electrolyser Technology and commercialize it for applications in sectors such as refineries, fertilizers, steel, and transportation. This initiative supports BHEL's commitment to the 'National Green Hydrogen Mission' and the 'Aatma Nirbhar Bharat Abhiyan' (Self-Reliant India Campaign). "The technology transfer from BARC will enable BHEL to enhance its capabilities in hydrogen production, contributing significantly to India's green energy goals and promoting self-reliance in advanced technologies," said Mr. Srivastava during the signing ceremony. The agreement marks a significant step towards sustainable energy solutions, leveraging indigenous technology to meet the growing demand for green hydrogen across various industries.

DFPCL Demonstrates Resilience amidst Challenges in Q4 FY2024



Pune, India: Deepak Fertilisers and Petrochemicals Corporation Limited (DFPCL), one of India's premier producers of industrial chemicals and fertilizers, reported strong performance in Q4 FY2024 despite facing significant challenges. The company announced a 12.6% increase in revenues quarter-on-quarter, reaching ₹.2086 crore, while operating EBITDA improved by 55.2% to ₹.438 crore, reflecting a margin increase from 15.2% to 21%. The fiscal year 2024 saw a decline in overall revenues by 23.2%, impacted by a 25% drop in the chemicals segment and a 21% decline

GWEC India appoints Girish Tanti as New Chair

GWEC India has appointed Girish Tanti, Vice-Chairman of Suzlon Group, as its new Chair to spearhead India's wind energy sector. Tanti, also Vice-Chair of GWEC globally, aims to collaborate with national and state governments to strengthen policy frameworks for both onshore and offshore wind energy. India, ranked fourth globally with 46 GW onshore wind capacity, positions Tanti to leverage his dual role effectively. He emphasized transformative initiatives and expressed commitment to enhancing GWEC's impact in India and globally. GWEC CEO Ben Backwell endorsed Tanti's appointment, foreseeing positive strides in India's wind energy landscape through sustained collaboration with stakeholders and policymakers.

in fertilizers due to lower monsoon levels and import disruptions. However, DFPCL managed to maintain a resilient operational stance, with EBITDA margins for the quarter improving significantly.

Key developments included the commissioning of an ammonia project, which achieved full production capacity, and a strategic long-term gas supply agreement with Equinor to enhance operational stability from 2026. Additionally, the board has recommended a dividend of 85%. Chairman and Managing Director Mr. Sailesh C. Mehta praised the company's strategic focus and innovation amidst adverse conditions, emphasizing the positive outlook for FY25 with anticipated above-average rainfall and robust demand across business segments.

TeamLease RegTech Report Highlights Compliance Challenges in Indian Chemical Industry

New Delhi, India: TeamLease RegTech, India's leading Regulatory Technology (Regtech) solutions company, has unveiled its latest report, "Simplifying Compliance Management for the Chemical Industry." This report sheds light on the complex compliance landscape faced by chemical manufacturers in India, emphasizing the need for streamlined regulatory processes.

The chemical industry, contributing 7% to India's GDP and 11% of exports, is a USD 220+ billion sector expected to reach USD 1 trillion by 2040. Despite its significant economic impact, the industry grapples with over 1,545 compliance obligations annually. A single manufacturing unit in Maharashtra must navigate 635 unique obligations, including 72 licenses, permissions, and approvals under 52 acts.

Rishi Agrawal, CEO of TeamLease RegTech, highlighted the industry's critical role in economic growth and job creation but stressed that compliance complexities hinder business expansion. The report calls for digital compliance solutions to simplify these processes, enabling smoother operations.

The report also discusses the regulatory burden imposed by acts such as the Chemical Weapons Convention Act and the Essential Commodities Act. It recommends reforms to improve ease of doing business, emphasizing the importance of new-age compliance management solutions for the industry's sustainable growth.

NMDC Unveils New State-of-the-art R&D Facility in Hyderabad

Hyderabad, India: India's largest iron ore producer, NMDC, has inaugurated a new state-of-the-art Research and Development (R&D) Center in Patancheru, Hyderabad. This facility aims to advance innovation in mineral processing and sustainable steel technology.

Vibrant Energy announces Vinay Pabba as next Chief Executive Officer

Vibrant Energy has appointed Vinay Pabba as its new CEO, succeeding Srini Viswanathan. Pabba, currently the company's COO, brings extensive experience from leading roles at Greenko, Virescent, and Brookfield. He expressed gratitude for Viswanathan's leadership and looks forward to driving Vibrant Energy's growth. Additionally, Anirban Das, the firm's CIO, will take on the role of Deputy CEO and CIO, with expanded responsibilities. Das has played a pivotal role in financing over USD2.5 billion in infrastructure debt in India, focusing on green energy initiatives since their inception.

Over the past five years, NMDC has invested more than ₹150 crores in R&D, with ₹50 crores dedicated to building the new center.

The eight-acre facility was inaugurated by Shri Amitava Mukherjee, CMD (Additional Charge), NMDC, alongside key officials including Shri Dilip Kumar Mohanty, Director (Production); Shri Vinay Kumar, Director (Technical); and Shri B. Vishwanath, CVO. Recognized as a Centre of Excellence by UNIDO and DSIR, NMDC's R&D has contributed significantly to mineral processing since 1970.Equipped with cutting-edge laboratories, the R&D Centre fosters innovation in sustainable mineral technology and ore beneficiation. It features sophisticated instruments like an automated mineral analyzer and an automated fusion bead-based X-ray fluorescence (XRF) analyzer, ensuring precise characterization of various minerals. The facility also includes a dedicated section for pelletization studies, providing crucial data for commercial pellet plant installations.

In his address, Shri Amitava Mukherjee emphasized NMDC's commitment to sustainable innovation: "Embracing our responsibility to innovate and lead the Indian Mining Industry towards a sustainable future through research and development, we open the doors to NMDC's new state-of-the-art R&D Center. As we stride forward to innovate and inspire, we are not just investing in research here, we are investing in India's Future." A unique feature of the new R&D Centre is the hydrogen reduction facility integrated with a microwave-assisted heating furnace, which is vital for developing green steel-making technologies. This aligns with global efforts to reduce carbon emissions and promote sustainability in the steel industry. The Centre boasts expertise in Mineralogical Characterization, Elemental Analysis, Bulk Materials Handling and Storage, Mineral Processing, and Coal and Coke Characterization. It will serve as a hub for collaboration with academic institutions and industry experts, supporting both corporate and public sector players in maximizing mineral recovery and ensuring mineral security for India. The NMDC R&D Centre is a significant step towards driving digital transformation and reinforcing the company's commitment to responsible mining and sustainable practices.

BASF Expands Performance Materials Capacity and Competencies in India

Mumbai, India: BASF India Limited is set to significantly increase the production c apacity of its Ultramid® polyamide (PA) and Ultradur® polybutylene terephthalate (PBT) at its compounding plants in Panoli, Gujarat, and Thane, Maharashtra. Additionally, the company will inaugurate its Polyurethane Technical Development Ce ntre India in Mumbai, to support market development for polyurethane applications across various industries. "The capacity expansion of Ultramid and Ultradur in Panoli and Thane, as well as the

Sachin Shende Appointed National Head of Sales and Marketing at Jitendra New EV Tech

Nashik-based electric vehicles manufacturer, **Jitendra New EV Tech, has appointed Sachin Shende as National Head of Sales and Marketing.** With over two decades in automotive sectors like 2W, 3W, and 4W commercial vehicles, Shende will drive sales and marketing strategies to expand Jitendra New EV Tech's footprint in B2B and commuter segments. His Mechanical Engineering background enhances his ability to innovate and ensure customer satisfaction, reinforcing Jitendra New EV Tech's position as a leader in the electric vehicles market.

inauguration of the Centre, shows BASF's commitment to enhancing local production and capabilities. With this Made-in-India-for-India strategy, BASF increases speed-to-market and stays close to customers, enabling shorter delivery times for products, solutions, and technical service," said Andy Postlethwaite, Senior Vice President, Performance Materials Asia Pacific, BASF.

With a production capacity increase of over 40% at Panoli and Thane, BASF aims to meet the growing demand for high-performance material solutions in India. The expanded capacity is expected to be operational by the second half of 2025. The new Polyurethane Technical Development Centre, spanning approximately 2,000 square meters, is equipped with advanced applications equipment. It offers comprehensive customer support services, including troubleshooting, customized formulations, line trials, and training sessions. The Centre will leverage BASF's global polyurethane network to provide innovative and advanced technical services, driving customer innovation alongside the Creation Centre at BASF's Innovation Campus in Mumbai.

Monash University and Tata Steel Sign MoU to Establish Sustainability-Focused Innovation Centre

Mumbai, India: Monash University and Tata Steel have signed a Memorandum of Understanding (MoU) to create a Centre for Innovation on Environment and Intelligent Manufacturing. This collaboration aims to address global challenges such as decarbonisation, sustainable resource recovery, and smart manufacturing technologies. Leveraging Monash University's expertise in materials science and advanced manufacturing, the MoU represents Tata Steel's first major R&D partnership with an Australian institution. This initiative will strengthen ties between Australia and India, offering educational and professional opportunities for students and academics, and fostering knowledge exchange.

Professor Doron Ben-Meir of Monash University highlighted the partnership's potential to transform industry-focused research into practical solutions. Professor Mainak Majumder emphasized the Centre's alignment with Monash's mission to create global impact through local innovation. T. V. Narendran, CEO of Tata Steel, noted the importance of sustainable manufacturing practices and the role of such collaborations in driving technological advancements. This partnership is part of Tata Steel's broader strategy to innovate and achieve sustainability goals, complementing recent MoUs with Imperial College London and The Henry Royce Institute. The Centre for Innovation will play a pivotal role in developing new materials and technologies, driving progress in sustainable manufacturing for the benefit of both nations.

Kalpataru Projects International Exploring Green Hydrogen Electrolyser Manufacturing

Gujrat, India: Kalpataru Projects International, formerly known as Kalpataru Power Transmission, is exploring opportunities to manufacture green hydrogen electrolysers as part of its product line diversification strategy. The company aims to expand its engineering, procurement, and construction (EPC) services into new sectors, focusing on the energy transition, particularly hydrogen and nuclear power. To support this initiative, Kalpataru Projects International is considering joint ventures or partnerships with foreign entities, utilizing

Ali Imran Naqvi Appointed Executive Director at Gensol Engineering Limited

Ali **Imran Naqvi has been appointed as Director (Executive) at Gensol Engineering Limited,** bringing over 14 years of experience in the renewable energy sector to his new role. He previously served as the CEO of Gensol Solar EPC (India), where he played a pivotal role in expanding the advisory portfolio to over 33,000 MW and successfully overseeing EPC projects totaling more than 600 MW across India. Naqvi's leadership at Gensol has been characterized by his strategic vision and operational expertise, contributing significantly to the company's growth and market presence. His appointment as Director (Executive) underscores his commitment to driving innovation and advancing Gensol Engineering's strategic initiatives in renewable energy and electric mobility solutions.

its existing giga factories in Raipur and Gandhinagar. The company is also monitoring developments in the nuclear energy sector, planning to extend its EPC offerings to include nuclear projects as they emerge. As one of India's largest engineering and construction firms, Kalpataru Projects International is committed to broadening its energy EPC portfolio to meet future market demands.

thyssenkrupp nucera India Hosts Chlor-Alkali Symposium to Foster Industry Advancements

Mumbai, India: thyssenkrupp nucera India recently organized a Chlor-Alkali Symposium in Mumbai, focusing on leveraging the potential of electrolysis technology. The event gathered stakeholders from India's caustic soda-chlorine industries alongside global electrolysis experts from thyssenkrupp nucera's network. Discussions revolved around current market challenges, technological advancements, membrane cell manufacturing, and operational issues within electrolysis plants.

Established as a dedicated entity in 2023, thyssenkrupp nucera India aims to enhance its presence in the stable chlor-alkali sector while expanding into the burgeoning green hydrogen market. Mr. Vaidyanathan Nagarajan, Managing Director of thyssenkrupp nucera India, highlighted the company's commitment to sustainability and innovation. He underscored their adoption of Alkaline Water Technology (AWE) for large-scale green hydrogen production and emphasized the company's extensive suite of technology solutions, including NaCl-ODC electrolysis technology and Bi-TAC filter-press technology. Mr. Nagarajan expressed confidence in thyssenkrupp nucera India's capability to deliver sustainable solutions with enhanced energy efficiency, longer membrane lifespan, and robust safety measures. He outlined their strategic focus on engineering, sales, and project execution (ESP) to support industry demands and customer objectives effectively. Mr. Kiran Joseph, Executive Director – Finance, highlighted the operational growth of thyssenkrupp nucera India's new hub in Vikhroli, Mumbai. This hub serves as a pivotal center for engineering and project execution, supporting both local operations and global endeavors across the Middle East, Asia, and Australia.

The symposium also addressed critical industry challenges such as energy intensity, decarbonization, and safety concerns associated with chlorine transportation and effluent treatment. Leaders from organizations like the Aditya Birla Group and UPL Ltd. emphasized the imperative for sustainable practices and the pivotal role of electrolysers in driving the clean energy transition. Overall, thyssenkrupp nucera India's symposium served as a platform to foster collaboration, innovation, and sustainable advancements within India's chlor-alkali and green hydrogen sectors.

Aramco Acquires 40% Stake in Gas & Oil Pakistan

Dhahran, Saudi Arabia: Aramco, one of the world's leading integrated energy and chemicals companies, has completed the acquisition of a 40% equity stake in Gas & Oil Pakistan Ltd. ("GO"). This investment marks Aramco's first downstream retail venture in Pakistan, signifying further progress in its global retail expansion. GO operates a diversified network of over 1,200 retail fuel stations across Pakistan, offering fuels, lubricants, and retail store services. The acquisition, initially announced in December 2023, enhances

Arvind Kumar Talan Appointed CFO of EESL

State-owned Energy Efficiency Services Limited (EESL) announced the appointment of **Arvind Kumar Talan as its new Chief Financial Officer (CFO).** Talan brings extensive experience in finance and corporate governance, having previously served as CFO at Jet Freight Logistics Ltd (JFLL) and IFFCO Ltd. In his new role, Talan will oversee all financial operations at EESL. As Company Secretary,

Closing ceremony are GO CEO Khalid Riaz, sitting left, and Aramco International Retail Director Nader Douhan, sitting right. Standing, from left, are GO board members Bilal Ansari and Shahzad Mubeen, Aramco Executive Vice President of Products & Customer

Aramco's presence in high-value markets. Earlier in March, Aramco also acquired a 100% stake in Esmax Distribución SpA ("Esmax"), a leading downstream fuels and lubricants retailer in Chile.

Yasser Mufti, Aramco Executive Vice President of Products & Customers, commented, "Our global retail expansion is gaining pace, and this acquisition is an important next step on our journey. Through our strategic partnership with GO, we look forward to supplying Aramco's high-quality products and services to valued customers in Pakistan. We are also delighted to welcome another high-caliber addition to Aramco's growing network of global partners and look forward to combining our resources and expertise to unlock new opportunities and further grow the Aramco brand overseas." This strategic partnership aims to unlock new opportunities for value creation and growth, reinforcing Aramco's commitment to expanding its global retail footprint.

Global Industrial Robot Shipments Surpass 500,000 in 2023 despite Revenue Slump

London, UK: According to the latest report from global market research firm Interact Analysis, worldwide shipments of industrial robots exceeded 500,000 units in 2023. Despite this stable shipment volume, the average price per unit decreased, marking a low point in terms of overall revenues. However, the long-term outlook remains positive, with an anticipated average annual growth rate of 3.7% from 2024 to 2028. The automotive sector, particularly in the Americas, experienced significant pressure, contributing to a 17.3% decline in regional growth. Conversely, the APAC region saw a slight increase, and EMEA remained stable. Notably, APAC accounted for 62% of global revenues, outpacing the Americas' 17% and EMEA's 22%.

Material handling, welding, and assembly dominated the market, collectively generating over 70% of revenues. The American market exhibited high concentration, with the top five suppliers capturing nearly 80% of revenues. Maya Xiao, Research Manager at Interact Analysis, noted the downward trend in robot prices, predicting a 3% annual decline from 2024 to 2028. This trend follows a temporary price rise due to the COVID-19 pandemic and inflation.

The comprehensive 6th edition of the Industrial Robots report offers detailed insights, including market size, forecast data, and supplier rankings, essential for understanding the evolving landscape of industrial robotics.

Manoj Jain Appointed as CMD, Bharat Electronics Limited (BEL)

Mr. Manoj Jain has assumed the role of Chairman & Managing Director of Navratna Defence PSU Bharat Electronics Limited (BEL). Previously serving as Director (R&D) and Director (Bangalore Complex), Mr. Jain's career with BEL began in 1991. With a BE in Electronics from REC Jaipur (MNIT), he has significantly contributed to R&D, including advancements in Defence Networks, Radar, and Electronic Warfare. Recognized with numerous awards, Mr. Jain has led various technical and managerial roles, ensuring innovation and self-reliance for BEL. He also held additional charge as Director (HR) from November 2022 to May 2023.

Volkswagen and Jindal's Vulcan Forge Alliance for Low Carbon Steel Production

Al Wusta, Oman: Volkswagen has partnered with Vulcan Green Steel, a subsidiary of the Jindal Steel Group, in a strategic move to integrate low carbon steel into its manufacturing processes. Vulcan Green Steel plans to commence production of automotive-grade and high-strength steels in Oman by 2027. Initially powered by natural gas, the Duqm facility will transition to renewable energy sources, reducing carbon emissions by 70%. The facility is scheduled to become operational in 2026. Dirk Grohe-Loheide, a Volkswagen board member, emphasized the importance of decarbonizing supply chains for Volkswagen's goal of achieving carbon neutrality by 2050. Volkswagen plans to source up to 300,000 tons of its annual steel requirements from Vulcan Green Steel.

Vulcan Green Steel's integrated approach in Oman encompasses iron ore mining and on-site production of green energy and hydrogen, ensuring a fully vertically integrated process for flat steel production, including secondary metallurgy.

Abraxas Power Selects McDermott for Canada's First Commercial Green Hydrogen and Ammonia Production Facility

Newfoundland Canada: Abraxas Power Corporation has awarded an Early Contractor Involvement (ECI) agreement to McDermott for the Exploits Valley Renewable Energy Corporation (EVREC) project in Central Newfoundland. This project will be Canada's first commercial green hydrogen and ammonia production facility, featuring a 530-turbine wind farm generating 3.5 GW of electricity and a 150 MW solar photovoltaic (PV) array. The facility will produce 165 kta of hydrogen and 5000 metric tons of ammonia per day. Rob Shaul, McDermott's Senior Vice President of Low Carbon Solutions, highlighted McDermott's extensive experience and integrated delivery model as key factors in securing the agreement. He emphasized that McDermott's approach would drive cost savings, reduce risk, and ensure quality assurance for Abraxas.

Under the agreement, McDermott will provide front-end engineering design (FEED), engineering, procurement, and construction (EPC) execution planning services, along with an open book EPC cost estimate for the hydrogen production, ammonia processing, and product storage components of the project. The work will be managed from McDermott's Houston office with support from its Gurgaon office in India. This landmark project signifies a major advancement in Canada's energy transition, leveraging McDermott's expertise to create a sustainable and efficient green hydrogen and ammonia production facility

ACHEMA 24: Global Showcase of Innovation in Process Industries

Frankfurt, Germany: ACHEMA 24, the premier international event for the process industries, brought together 2800 exhibitors from over 50 countries, showcasing groundbreaking innovations across sectors such as Chemical, Pharma, Engineering, Biotech, and Environmental took place in Frankfurt, Germany this June. The event featured six innovation stages focusing on Process, Pharma, Green, Lab, Digital, and Hydrogen technologies. Attendees were captivated by demonstrations of remotely controlled robots in chemical plant and laboratory mock scenarios. Insights into global laboratory design, sustainability, and digital infrastructure were provided by the American Scientific Equipment and Furniture Association (SEFA). Advancements in data integration and standardization were highlighted at the DEXPI Data Model Integration Congress. Other notable events included the ISSA Symposium on hazardous substances in maintenance, the ELRIG Drug Discovery Forum, the VCW sustainable green chemical strategies event, and the VDI platform for production engineers. INDIA DAY spotlighted the contributions of 187 Indian exhibitors.

Special attention was given to the hydrogen economy, with solutions for hydrogen handling, transport, and storage presented in Hall 6.0. ACHEMA's interdisciplinary approach facilitated unparalleled knowledge sharing among manufacturers, users, developers, and scientists, offering comprehensive insights into process technology. The event encompassed 12 exhibition groups, covering Engineering, Digital Hub, Research and Innovation, Laboratory Techniques, Mechanical Processes, Pharmaceutical Packaging, and more. This diverse scope underscored ACHEMA's role as a pivotal platform for industry innovation.

German Process Technology Sector Adapts to Decarbonization Challenges

Frankfurt, Germany: As Germany pursues decarbonization, the mechanical and plant engineering sector, particularly process technology, is pivotal. Applications in this field are crucial for producing green hydrogen, a key focus at ACHEMA 2024, the world's leading process industry trade fair. "Hydrogen's integration into industry requires expertise in suitable materials and media," says Dr. Laura Dorfer, Managing Director of the VDMA Valves Association. "German manufacturers are established partners in hydrogen processes, from production to utilization."

The valves sector experienced a 13% increase in foreign sales early in 2024, despite a 9% domestic decline. Exports rose 5.2% to EUR 5.1 billion in 2023, with China as the top market. Liquid pump exports grew by 2.9% to EUR 6.3 billion in 2023 but fell 6.8% in early 2024. The compressors sector saw a 4.4% rise in exports to EUR 5.7 billion in 2023, maintaining stability in 2024 despite a slight dip. Process engineering exports dropped 6.7% early in 2024, while turnover increased by 6% in April, driven by non-euro countries. Despite challenges, the sector remains resilient. VDMA Executive Director Christoph Singrün expects stable sales, emphasizing the importance of innovation amidst regulatory and economic pressures.

Solenis and PhaBuilder Collaborate to Develop PHA-Based Materials

Delaware, US: Solenis, a global producer of specialty chemicals for water-intensive industries, has entered into an agreement with Beijing PhaBuilder Biotechnology Co., Ltd. (PhaBuilder) to jointly develop Polyhydroxyalkanoate (PHA)-based technology for the paper packaging market. William (Bill) Kuecker, Senior Director of Global Strategic Marketing at Solenis, emphasized that the collaboration will bring unique technology to the paper packaging market, addressing the growing demand for sustainable packaging solutions. Sherry Xu, President of PhaBuilder, highlighted that the new technology will reduce environmental impact and promote a greener future. Ed Connors, Chief Business Officer, Americas, and Global Business President, Consumer Solutions at Solenis, expressed satisfaction with the strategic agreement, stating that it marks a significant milestone in Solenis' commitment to sustainability. This partnership aims to enhance the application of PHA-based materials, advancing the sustainability goals of both companies and their customers.

hte Wins NEN Tender for FCC Co-Processing of Biogenic Feedstocks

Heidelberg, Germany: hte, the high throughput experimentation company, has been contracted by NEN, the Royal Dutch Standardization Institute, to provide R&D services in the field of Fluid Catalytic Cracking (FCC). The project focuses on finding verifiable alternatives to radiocarbon analyses for determining bio-based carbon contents in refinery co-processing applications, specifically using fast-pyrolysis bio-oils (FPBO).

FCC is a crucial process in modern refineries, converting hydrocarbon fractions from crude oil into valuable products like olefinic gases and gasoline. The co-processing of biogenic feedstocks in FCC offers a viable pathway for refineries to contribute to global decarbonization efforts and comply with stringent regulations. The European Commission, particularly the Joint Research Centers (JRCs), is keen on identifying an alternative to Carbon14 radiocarbon analyses, as preliminary investigations show it is insufficiently sensitive for low-level biogenic carbon content determination.-

This setup generates data to determine biogenic carbon content distribution in FCC FPBO co-processing via total mass, carbon mass, energy balancing, and delta yield methods. Comprehensive physical and chemical data on feeds and all product fractions were collected to support various balancing methods, including bio-based carbon determination via EN 16640 (Carbon14 AMS detection).

Wolfram Stichert, CEO of hte, commented, "We are excited and proud of our technology's contribution to potentially developing a new standard for allocating biogenic carbon content in the refining industry. Our MDU has proven valuable for FCC laboratory-scale testing, catalyst benchmarking, yield predictions, and co-processing biogenic feedstocks. We are confident this versatile technology and the developed methodology will help refiners tackle the challenges of decarbonization."

The Future of India's Resin Industry: Innovation, Growth, and Challenges

Mumbai, India: The chemical and petrochemical industry in India plays a pivotal role in the country's manufacturing sector and economic growth. Ranked 6th globally in chemical production and 3rd in Asia, India's chemical sector is a cornerstone for various industries, including textiles, paper, paints, pharmaceuticals, and agrochemicals. The chemicals market is projected to employ one million people by 2024 and grow at a CAGR of 3.19% from 2024 to 2029. The industry's contribution to GDP is substantial, targeting 383 billion USD by 2030, with India holding a 4% share of global chemical production.

Epoxy Resin Market Growth - The Indian epoxy resin market is experiencing robust growth, driven by its extensive applications in construction, woodworking, and manufacturing. The market size is estimated at 172 kilotonnes in 2024 and is expected to reach 251.57 kilotonnes by 2029, growing at a CAGR of 7.90%. Globally, the epoxy resins market is projected to grow from 3.55 million tons in 2024 to 4.20 million tons by 2029, at a CAGR of 3.41%.

- Market Share Analysis: In 2023, paints and coatings dominated the epoxy resin market with a 37.7% share. Solid epoxy resin held the largest market share at 52.1%, valued for its durability and versatility.

Industry Ecosystem and Technological Advancements

- Infrastructure Development: Large-scale projects such as highways, airports, and metro networks drive substantial demand for epoxy resins due to their superior protection against corrosion, abrasion, and weathering.
- Technological Advancements: Innovations in epoxy resin formulations improve performance and sustainability, expanding their use across diverse industries like automotive, electronics, aerospace, and marine. Continuous R&D efforts lead to improved curing technologies, enhancing processing efficiency and expanding application possibilities.

Challenges Facing the Resin Industry

Despite its growth, the resin industry faces several challenges:

- Volatility in Raw Material Prices: Fluctuations in prices of key precursors like bisphenol-A (BPA) and epichlorohydrin (ECH) can impact profitability and market stability.
- Environmental Concerns: Production and disposal of epoxy resins pose ecological challenges, necessitating investment in sustainable alternatives.
- Regulatory Constraints: Compliance with stringent environmental regulations regarding VOC emissions and hazardous waste disposal requires investment in pollution control measures.
- Competition from Alternative Materials: Epoxy resins face competition from materials like polyurethane, polyester, vinyl ester, and phenolic resins, which may offer better flexibility, lower cost, or higher temperature resistance.

Government Initiatives and Future Prospects

The Indian government's "Atmanirbhar Bharat" initiative promotes domestic production of chemicals, including resins, reducing dependency on imports. The Directorate General of Trade Remedies (DGTR) is also considering imposing quantitative restrictions on imports from countries like China, USA, Taiwan, and Russia to support local manufacturers.

Import and Export Trends: In FY23, polymer imports grew by 39.7% to 10.6 million tonnes, driven by lower import realizations. However, the decline in import realizations, such as a 22.7% drop for suspension grade PVC resins, has impacted domestic prices. India imports polymers from countries like China, USA, UAE, and Saudi Arabia. The Industry's growth is expected to be driven by advancements in technology, increased demand in key sectors, and supportive government policies. Addressing challenges like raw material price volatility, environmental concerns, and regulatory constraints will be crucial. Investment in sustainable practices and leveraging technological advancements, such as digitalization and artificial intelligence, can enhance the industry's resilience and adaptability. With strategic planning and innovation, the Indian resin industry is poised to achieve significant milestones, contributing substantially to the country's economic growth and industrial development. ■

India Approves ₹ 7,453 Crore Scheme for 1 GW Offshore Wind Energy Projects

New Delhi, India: The Union Cabinet has granted approval for a Viability Gap Funding (VGF) scheme totaling ₹7,453 crore to facilitate the development of one gigawatt (GW) of offshore wind energy projects in Gujarat and Tamil Nadu. This initiative marks India's maiden venture into offshore wind energy. Under the VGF scheme, ₹6,853 crore will be allocated for the installation and commissioning of 500 megawatts (MW) of wind energy projects off the coasts of both Gujarat and Tamil Nadu. Additionally, ₹600 crore has been earmarked for upgrading two ports to cater to the logistical requirements of these offshore projects.

Upon successful completion, the 1 GW offshore wind projects are projected to generate approximately 3.72 billion units of renewable electricity annually. This is expected to mitigate approximately 2.98 million tons of CO2 equivalent emissions annually over a period of 25 years. The scheme aims to kick-start the growth of offshore wind energy in India while fostering an enabling environment for further ocean-based economic activities. It is envisioned that this ecosystem will facilitate the development of 37 GW of offshore wind energy, necessitating an investment of around ₹4, 50,000 crore. This landmark initiative underscores India's commitment to expanding its renewable energy capacity and reducing carbon emissions, aligning with global efforts towards sustainable development and combating climate change.

Godavari Biorefineries Inaugurates Multi-Purpose Specialty Chemicals Plant

Maharashtra, India: Godavari Biorefineries Ltd. (GBL), a leading supplier of alcohol-based chemicals, officially inaugurated its new multi-purpose specialty chemicals plant in Sakharwadi, near Shirdi, Maharashtra. The plant has been operational for over a year and was formally opened by Prof. M.M. Sharma, former Director of the Institute of Chemical Technology, in the presence of the Consul General of the Kingdom of the Netherlands, Mr. Jong De Bart, and senior GBL officials including Mr. Samir Somaiya, Chairman & Managing Director, and Dr. Sangeeta Srivastava, Executive Director. The new facility will enhance GBL's capacity to produce bio-based specialty chemicals, reducing imports and opening new export markets. One of the key products is ethyl vinyl ether (EVE), used in agrochemicals, aroma chemicals, pharmaceuticals, and lube oil additives. GBL's innovative production route uses ethanol and acetaldehyde from bio-based materials, offering a low-carbon footprint alternative to traditional methods.

Prof. Sharma highlighted acetaldehyde's potential as a platform chemical for GBL, enabling the production of a wide range of fine and specialty chemicals. Mr. Somaiya emphasized GBL's strategic shift from commodity chemicals to value-added bio-based chemicals, which now constitute about 50% of the company's chemical sales. GBL plans to valorize bagasse, producing high-quality cellulose and lignin derivatives. The company is also seeking global partnerships to drive product offtake, with ongoing collaborations for bio-based esters and aroma chemicals. Mr. Somaiya affirmed GBL's commitment to sustainability, leveraging biomass for food, electricity, biochemicals, and biofuels, aligning with their mission to protect the planet.

ONGC and EverEnviro to Jointly Develop 10 Compressed Biogas Plants across India

Mumbai, India: Oil and Natural Gas Corporation (ONGC) has announced a 50:50 joint venture (JV) with EverEnviro Resource Management to establish 10 compressed biogas (CBG) plants across India. The companies have signed a preliminary agreement to formalize the JV, marking a significant step in advancing renewable energy production in the country. The JV will utilize diverse feedstocks, including agricultural waste, agro-industrial waste, energy crops, and municipal solid waste (MSW), aiming to mitigate approximately 750,000 tonnes of CO2 equivalent annually. EverEnviro, established in 2019 by Eversource Capital—a JV between the Everstone Group and Lightsource—specializes in waste management solutions and is currently working on 20 CBG projects with an investment of around ₹2,000 crore. The company plans to build over 100 CBG plants nationwide.

ONGC's venture into the non-fossil fuel sector includes

establishing solar, wind, and biofuel facilities, aligning with its goal to achieve net-zero emissions by 2038. This collaboration with EverEnviro underscores ONGC's commitment to transitioning to clean energy by leveraging agro-industrial waste. This initiative is in line with the government's push for state and private players to invest in the CBG sector, aiming to reduce natural gas imports and promote sustainable energy practices.

GAIL Inaugurates First Green Hydrogen Plant in Madhya Pradesh

Madhya Pradesh, India: Marking a significant advancement in alternate energy, GAIL (India) Limited has inaugurated its first Green Hydrogen Plant at GAIL Vijaipur in Madhya Pradesh. The plant was inaugurated by Shri Pankaj Jain, Secretary, Ministry of Petroleum & Natural Gas, in the presence of GAIL Chairman and Managing Director Shri Sandeep Gupta, Director (Projects) Shri Deepak Gupta, Director (Human Resources) Shri Ayush Gupta, and other senior officials. The Green Hydrogen plant, equipped with 10MW PEM (Proton Exchange Membrane) Electrolyzer units, has a production capacity of 4.3 TPD (tons per day) of hydrogen through the electrolysis of water using renewable power. The hydrogen produced will have a purity level of 99.999% (by volume) and will be produced at a pressure of 30 Kg/cm^2.

Initially, the hydrogen will be used as a fuel along with natural gas for various processes and equipment in the existing plant at Vijaipur. Additionally, plans are in place to dispense hydrogen to retail customers in nearby areas, transported via high-pressure cascades. To support the plant's renewable power needs, GAIL is setting up around 20 MW of solar power plants at Vijaipur, including both ground-mounted and floating installations. This initiative aligns with the National Green Hydrogen Mission and underscores GAIL's commitment to sustainable energy solutions.

GPS Renewables and SAF One to Establish India's First Sustainable Aviation Fuel Facility

Madhya Pradesh, India: GPS Renewables, a leader in clean fuel technologies, has partnered with Dubai-based SAF One to establish a sustainable aviation fuel (SAF) production facility in India. The facility aims to produce between 20 and 30 million liters of SAF annually using lignocellulosic waste feedstock, which consists of residual dry plant matter. This initiative aligns with India's strategy to mandate SAF blending in aviation fuel, targeting a blend of one to five percent by 2027. The collaboration aims to accelerate SAF production, supporting India's goals for cleaner aviation fuel.

GPS Renewables has a significant track record in biofuel technology and project development, having established over 100 biogas plants, including Asia's largest renewable natural gas (RNG) plant based on municipal solid waste (MSW) in Indore, Madhya Pradesh. This new venture leverages GPS Renewables' extensive experience in green energy projects and SAF One's expertise in the aviation sector. EY served as the exclusive M&A investment banker for GPS Renewables in this transaction, underscoring the strategic importance and potential impact of this partnership. The facility represents a major step forward in transforming India's aviation sector towards sustainability, potentially setting a precedent for future green initiatives in the industry

BPCL announces Plans for New ₹50,000-Crore Refinery

Mumbai, India: Bharat Petroleum Corporation Limited (BPCL) has unveiled plans to establish a new 12 MTPA refinery with an investment of ₹50,000 crore. This project aims to meet India's growing demand for fuel and petrochemicals. Potential locations under consideration include Andhra Pradesh, Uttar Pradesh, and Gujarat. Currently, BPCL operates three refineries in Mumbai, Kochi, and Bina, Madhya Pradesh, with a combined refining capacity of approximately 36 MTPA. The new refinery will bolster BPCL's total refining capacity to 45 MTPA by FY29.

BPCL also plans a substantial investment of ₹1.7 lakh crore over the next five years, focusing on oil refining, petrochemicals, and clean energy initiatives. Out of this, ₹75,000 crore is earmarked specifically for refinery and petrochemical projects.

India's fuel demand reached 233.276 million tonnes (MT) in FY24, up from 223.021 MT the previous year. To address the rising oil demand, the government aims to increase the country's refining capacity by nearly 80%, from the current 252 MTPA to about 450 MTPA by 2030. BPCL's ambitious investment and expansion plans are poised to significantly contribute to this national goal, ensuring adequate supply and supporting India's energy needs.

Yara Opens 24 MW Renewable Hydrogen Plant at Herøya, Norway

Prime Minister Jonas Gahr Støre officially opening Yara's renewable hydrogen plant

Norway, Europe: Yara International has inaugurated its renewable hydrogen plant at Herøya Industrial Park, marking a significant milestone for the company and the decarbonization of the food value chain. The 24 MW plant, the largest of its kind in Europe, was officially opened by Norwegian Prime Minister Jonas Gahr Støre and Yara CEO Svein Tore Holsether. The plant produces renewable hydrogen and ammonia through the electrolysis of water using renewable energy, replacing natural gas as feedstock. This process will annually cut 41,000 tonnes of CO2 emissions from the site. The first tonnes of fertilizers made from this renewable ammonia have already been delivered to Lantmännen, a key partner in the decarbonization effort.

"This is a major milestone for Yara and for the decarbonization of the food value chain, shipping fuel, and other energy-intensive industries," said Holsether. "We are proud to have delivered the first low-carbon footprint fertilizers, showcasing the importance of collaboration across the food value chain." The new portfolio, Yara Climate Choice, features these low-carbon fertilizers that benefit crops while reducing climate impact. Yara is also working on producing low-carbon ammonia with CCS (Carbon Capture and Storage) to further enable the hydrogen economy and develop markets for low-emission ammonia.

Hans Olav Raen, CEO of Yara Clean Ammonia, emphasized the urgency of acting on multiple fronts to meet the Paris Agreement goals. Yara has reduced its emissions by 45% since 2005 and aims to continue this trajectory by investing in renewable energy, CCS, and advanced technologies.

"Companies that take the green transition seriously will gain a competitive advantage," Holsether added. "With our strategy to deliver decarbonized solutions quickly and at scale, Yara is uniquely positioned to benefit shareholders, customers, employees, and society at large."

JSW, Juniper, Ganeko Secure Capacities in SJVN's 1,500 MW Hybrid Project

Himachal Pradesh, India: Ampin Energy, Ganeko Solar (Solarpack), Inaayu Renewables (EverGreen Power), Juniper Green Energy, Datta Power Infra, JSW Neo Energy, and Avaada Energy have secured capacities in SJVN Green Energy's (SGEL) 1,500 MW ISTS-connected hybrid-II tender. The capacities were allocated through an e-reverse auction conducted by SJVN. JSW Neo Energy and Ganeko Solar each secured 300 MW of wind-solar hybrid capacity. AmpIn Energy and Juniper Green Energy were awarded 150 MW each, Datta Power Infra secured 70 MW, and Inaayu Renewables received 60 MW. Avaada Energy was the largest winner with 750 MW capacity.

AmpIn Energy, Ganeko Solar, Inaayu Renewables, Juniper Green Energy, and Datta Power Infra secured their capacities with a quoted tariff of ₹3.41 per unit, while JSW Neo Energy and Avaada Energy won with a quoted tariff of ₹3.42 per unit.SJVN invited bids for this project in February, selecting hybrid power developers through tariff-based competitive bidding. The successful bidders will enter into a 25-year power purchase agreement (PPA) with SJVN, which serves as the intermediary procurer and renewable energy implementing agency. SJVN is a joint venture between the Government of India and the Himachal Pradesh government.

Jakson Green Selected for World's First CO2-to-4G Ethanol Project in India

New Delhi, India: In a ground breaking move for India's clean energy sector, Jakson Green has been chosen as the Engineering, Procurement, and Construction (EPC) partner for the world's first project converting flue gas CO2 into 4G ethanol. Spearheaded by NTPC Energy Technology Research Alliance (NETRA), the R&D arm of NTPC Limited, the project will be located in Lara, Chhattisgarh, and is expected to be operational within two years. This innovative project aims to produce 10 tons of 4G ethanol per day from flue gases by capturing 25 tons of CO2 daily and generating 3 tons of green hydrogen daily through a 7.5 MW electrolyser. Advanced microbial fermentation technology from LanzaTech Inc. will transform the captured CO2 and hydrogen into ethanol.

Kannan Krishnan, Joint Managing Director of Jakson Green Private Limited, highlighted the project's significance: "We are immensely proud to continue our partnership with NTPC to establish this landmark project. Increasing ethanol production is crucial for achieving India's blending goals, enhancing energy security, and fostering a cleaner future. This transformative project positions us at the forefront of the clean energy revolution."Jakson Green's involvement in this project cements its leadership in India's green molecule space. With over 8,500 TPA of green hydrogen and its derivatives production capacity under development across six significant Power-to-X projects, Jakson Green is set to drive India's clean energy transition and contribute to a sustainable future.

Wärtsilä Launches World's First Large-Scale 100% Hydrogen-Ready Engine Power Plant

Helsinki, Finland: Wärtsilä has unveiled the world's first large-scale 100% hydrogen-ready engine power plant, a landmark achievement in the shift towards renewable energy. The innovative power plant can run on natural gas and up to 25 vol% hydrogen blends, according to a recent company press release. "The Wärtsilä 31 engine platform, which forms the backbone of this hydrogen-ready power plant, is the most efficient in the world," the company stated. "It can synchronize with the grid within 30 seconds from start command, ensuring energy security through fuel flexibility, and offers unmatched load following capabilities and high part-load efficiency. With over 1 million running hours and more than 1,000 MW installed capacity globally, it exemplifies advanced engineering."

Anders Lindberg, President of Wärtsilä Energy, remarked, "This is a major milestone for us as a company and for the energy transition more broadly. Our hydrogen-ready engines will enable the 100% renewable power systems of tomorrow." The 100% hydrogen-ready engine will be available for orders in 2025, with deliveries beginning in 2026. This breakthrough is set to play a crucial role in advancing sustainable energy solutions and enhancing fuel flexibility in power generation.

BluPine Energy Inks Deal with Dalmia Cement for 46.87 MW Solar Plant in Karnataka

New Delhi, India: BluPine Energy announced on Tuesday that it has signed a Power Purchase Agreement (PPA) with Dalmia Cement (Bharat) Limited for a 46.87 MW solar power project in Karnataka. This project, structured under a captive model, is expected to generate approximately 93.75 million units (MUs) of electricity annually and offset over 85,000 tonnes of CO2 emissions each year. Neerav Nanavaty, CEO of BluPine Energy, commented, "The solar plant in Karnataka will not only produce clean energy but also foster local economic growth and support environmental sustainability. This project will help reduce operating costs and improve energy efficiency."

The addition of this solar plant boosts BluPine Energy's total renewables capacity to 2.4 GW, with over 725 MW of operational capacity across 27 sites in seven states in India. Established by Actis, a global investor, BluPine Energy continues to lead in renewable energy services, building sustainable infrastructure across the country. This partnership marks a significant step towards sustainable energy solutions, reinforcing both companies' commitments to reducing carbon footprints and promoting green energy in India.■

Membrane Technology – Latest trends relevant to the Indian scenario for sustainable solutions

Membrane technology plays a crucial role in water purification, wastewater treatment, and improving industrial processes through effective separation and filtration. In India, the membrane manufacturing sector is limited, with most products imported from the USA, Europe, Japan, or South Korea. **Vatsal Shah, Research Scientist, Vipul Organics,** underscores the importance of innovation, government backing, and local production to enhance the influence of membrane technology. His emphasis is on sustainable solutions for securing water resources, promoting resource efficiency, and minimizing environmental impact across India.

One of the most pressing issues of the 21st Century is the sustainable use of water. In India, about half billion people still lack access to safely managed drinking water. The problem is not just restricted to rural India, but also affluent cities like Bangalore and Chennai have faced record drought levels. These cities were very close to reaching "Day Zeros", meaning that the city has run out of all its water and cannot cater to its needs. People need to queue in lines to claim their rations of the region's most precious commodity- clean drinking water. Perhaps that is why it is suggested that water will be the oil of the 21st Century!

Given this challenge of drinking water scarcity that poses the India and world at large, effective water management has become extremely important and the role of membrane technology in dealing with the same shall be significant.

History of Membrane Filters

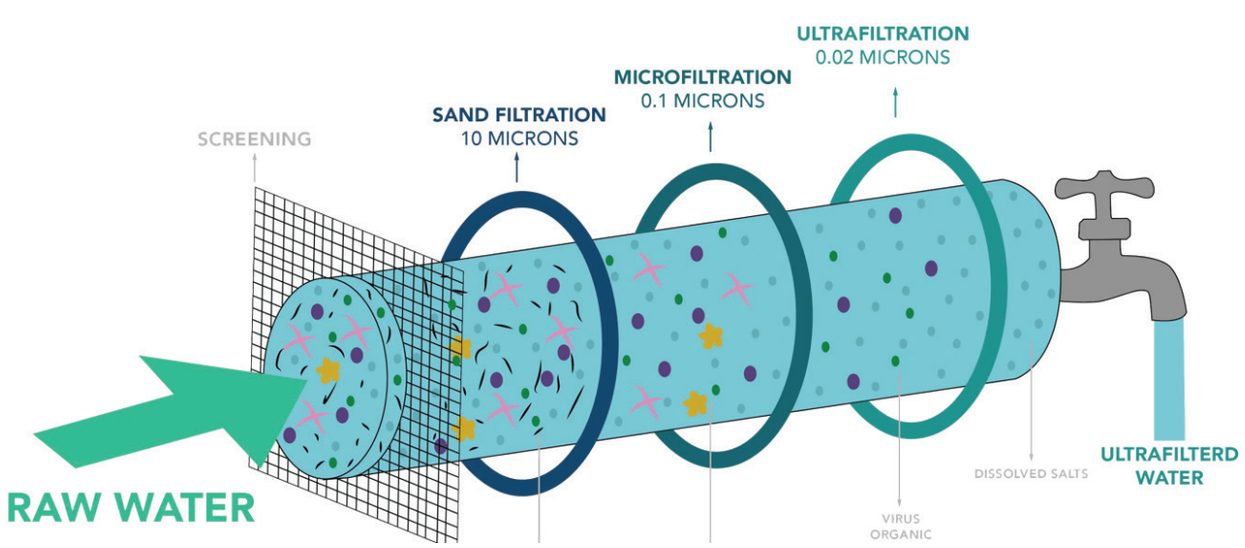
The first significant application of the membrane-based separation was at the end of World War II when drinking water supplies had broken down around Europe and filters were needed to test for the safety of water. Although membranes were becoming popular, until the 1960s membrane industry was still in its infant stage, with limited application in laboratory setups or small specialised industrial separations. It was after the seminal discovery made by our Indian scientist Sourirajan in collaboration with his colleague Leob, to produce defect-free asymmetric reverse osmosis (RO) membranes that had permeation rates 10 times higher than any other membrane available at the time. Seawater desalination on a large commercial scale then became a reality. Today, membrane technology has become exceedingly mature and so many applications such as sterile filtration, haemodialysis, water purification, gas separation and many others are unimaginable without the use of membranes.

Understanding the Diverse Applications of Membrane Technology

Membrane technology involves the use of semi-permeable membranes to selectively separate components in a fluid mixture based on their size, shape, and chemical properties. This versatile technology finds applications in diverse sectors including water treatment, food and beverage processing, pharmaceuticals, and environmental protection. Membrane filtration is predominantly a pressure-driven process and depending on the type of application, membranes with specific pore size ranges need to be used. These are categorised into 4 main types listed below:

Microfiltration (MF): MF membranes have pore sizes in the range of 100-1000 nm. These membranes can filter out large suspended solids such as particulates, colloids, fat and bacteria. However, it allows viruses, proteins, polysaccharides and other relatively smaller molecules to permeate through. They play an important role in primary disinfection and clarification of the uptake water stream from the reservoirs, before entering UF units to produce potable water. Some other important applications include cold sterilization in the pharmaceutical and beverage industry, separation of casein from whey protein in the dairy industry and production of paints and adhesives. Many times MF membranes are used in pre-treating feed streams to block out larger molecules, before entering UF or RO systems.

Ultrafiltration (UF): UF membranes have pore sizes in the range of 2-100 nm. Unlike MF membranes, UF membranes are capable of retaining polysaccharides, proteins, viruses and other relatively larger molecules.



Raw water is typically ultrafiltered to make it potable.

They, however, allow sugars, amino acids, multivalent and monovalent ions and water to permeate through. UF plays an important role in the production of potable water. Along with MF membranes, UF membranes are also widely used in membrane bioreactors for wastewater treatment and is preferred over the conventional activated sludge systems because of several advantages such as consistent permeate quality, smaller footprint requirement, pathogen-free permeate, and most importantly no chemical disinfection requirement. UF is also widely used in the dairy industry for whey protein concentration, cheese production, and removal of pathogens from milk. UF membranes are also used to pre-treat feed streams entering RO systems, for example in the application of seawater desalination.

Nanofiltration (NF) : NF lies in a transition region between pure RO and pure UF with pore sizes in the range of 0.1-1 nm. It is sometimes referred to as loose RO or low-pressure RO. NF membranes are used for the removal of micropollutants and multivalent ions and have partial retention for univalent ions. Their applications include water softening, removal of heavy metals from wastewater, removal of pesticides from groundwater, and wastewater recycling in laundries.

Reverse osmosis (RO): RO membranes have pore sizes that are so small (less than 0.1 nm) that it filters out almost everything such as salts and metallic ions and only allows water to pass through. One of the most important applications of RO membranes is seawater desalination, which is very popular in areas with very limited surface and groundwater. Also, RO membranes are widely used around the globe in household drinking water purification systems to further improve the quality of water. RO systems are also used in industry to ensure that the water heated in the boiler to produce steam to heat various processes, is devoid of salts and minerals, as otherwise would lead to scaling or corrosion.

Indian Context

Today the global membrane market is estimated to be around 10 billion USD of which India constitutes less than 10%. The growth of membrane industry in India in the coming decade is going to be exponential across various sectors

Access to Safe Drinking Water: The cities are expanding and hence the municipal authorities must also expand their centralised water purification systems. Membranes can help them retrofit their existing systems to expand capacity without needing a larger footprint. As people are becoming more conscious of the quality of water they drink, the home water filter market is also grow quite rapidly. Even in rural areas, government must fund water purification systems to ensure safe drinking water reaches every household.

Industrial waste water treatment: Any chemical factory, must treat its wastewater before discharge. The conventional wastewater treatment systems consist of 3 stages of water treatment. Adoption of innovative membrane systems such as membrane bioreactor can considerably simplify the system and also help reduce the capital costs.

In India, for the establishment of any new chemical factory, environmental clearance (EC) must be sought. Most often, the EC mandates a ZLD (Zero Liquid Discharge) system to be implemented meaning, that factory is not permitted to discharge any effluent outside its premise and that it must recover and recycle all of its wastewater. ZLD systems are certainly an added costs for the industries but membrane based recovery systems can play a very important role in bringing these costs down. Appropriate process design and membrane selection by a membrane expert is essential.

Domestic waste water treatment: The wastewater generated by cities must be treated before discharge. Here again membranes can help reduce the footprint area requirement compared to conventional activated sludge systems. Use of UF and RO can in fact also allow a majority of this water to be recycled and reused.

Growth of Pharma and Biopharma industries: The growth of pharma and biopharma industries in India has been phenomenal and is still expected to double its size in the next 5 years. Both these industries rely on quality membranes for its filtration needs such as sterilisation, organic solvent separations, fermentation and cell cultures.

Membranes used in industry on a large scale

Challenges and Opportunities

Government policy implementation: Policy frameworks incentivize investments in advanced membrane systems, driving innovation and market expansion. While water recovery and reuse is a costly affair, strict government enforcement and mandatory water treatment systems will push the adoption of membrane based separation systems. Mandatory implementation of ZLD systems is certainly a step in the right direction.

Push for Make-in-India: There are only a handful of companies that manufacture membranes in India. Most of these membranes are imported either from the USA, Europe, Japan or South Korea. The costs of these membranes can be quite high and hence an impediment to its adoption. Local manufacturing will not only bring these costs down but also foster tailor-made solutions for Indian industrial needs.

Replacement and Energy costs: Membranes undergo fouling over time, where the filtration performance of the membrane deteriorates over time. Fouled membranes must be replaced every few months or years depending on its application. Moreover some RO-systems require very high pressures for its filtration which require very high energy input. Collaborative research partnerships between academia, industry, and government institutions shall accelerate innovation cycles and foster technological advancements in improving the efficiency of the membranes and reduce its fouling tendency.

Recycling Membranes: As mentioned before, fouled membranes must be replaced with new ones periodically. This has led to a new problem of membrane disposal. Since majority of these filtration membranes are made from a polymeric material, they are non-biodegradable. Research is now being promoted to repurpose the old RO membranes that have completed its life cycle for UF or MF applications.

Conclusion

Membrane technology stands as a catalyst in India's drive towards sustainable industrial progress. By embracing innovations in materials science, digitalization, and eco-friendly technologies, Indian industries can optimize resource use, minimize environmental footprint, and bolster global competitiveness. Continued evolution of membrane technologies is set to play a pivotal role across diverse sectors, shaping a resilient and sustainable future for India. ■

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Emphasizing Applied Research: Key to Achieving Technological Self-Reliance in Membrane Manufacturing

India imports approximately half a million membrane elements annually, amounting to roughly USD 16 million. To foster a strong indigenous membrane industry, continuous R&D using locally sourced materials is essential. This demands substantial funding and resources, which cannot solely be borne by product costs. While the Indian government supports academic research, there is presently no provision for direct funding of industrial research, a gap requiring attention. **Satyajai Mayor, Managing Director, Permionics Membranes Pvt. Ltd.,** highlights the growing demand and underscores the importance of supporting applied research within industries in an exclusive interview with **Mittravinda Ranjan**

SATYAJAI MAYOR
Managing Director
Permionics Membranes Pvt. Ltd.

What is the current scenario of membrane technologies in India?

Membranes are not standalone solutions but these are integrated into comprehensive systems. The market primarily revolves around membrane elements, which constitute 20-25% of the total system cost. India imports around half a million membrane elements annually that translates to about ₹1.2 billion (approximately USD16 million). The largest markets for membranes are the USA, China, and the Middle East. The USA, often referred to as the Mecca of membrane technology, whereas China is the biggest consumer. In the US, entire rivers are treated using membranes, a luxury India cannot afford due to geographical and legislative variances.

Overall, the size and scale of India's membrane market align with the country's industrial needs and geographic constraints. In the past, educating the industry about membranes was a challenge. Today, the demand for membranes as well as the knowledge about improving process efficiency, reducing manufacturing costs, lowering discharge volumes and pollutants have grown significantly. As a membranes specialist, I am optimistic about the current scale and future growth potential of the market in India.

How do you see the landscape evolve in the foreseeable future?

We anticipate a growth rate of 20-25% per year for the membrane technology market in India. The industrial use of membranes is relatively small compared to infrastructure applications like desalination plants and large sewage water recycling plants in cities.

Over the last few decades, companies such as Indian Rayon, Gujarat Heavy Chemicals, and Adani Nirma etc. have installed large desalination capacities due to their reliance on seawater in Gujarat. India still has access to freshwater reservoirs, which are a more cost-effective water source compared to advanced filtration techniques involving membranes. However, Tamil Nadu, Andhra Pradesh, and Gujarat have spurred investments in setting up desalination plants along the coast, with membrane technology as the cornerstone.

COVID-19 was a turning point for industries. Post-pandemic, Indian pharmaceutical and chemical manufacturers began expanding and strengthening their supply chains to reduce dependence on imports. As increasing industrial capacities demand greater water usage and effluent management, governments are now pressuring industries to recycle water and comply with regulatory norms. This shift has significantly boosted the adoption of membrane technologies.

New sectors such as solar wafer and semiconductor manufacturing industries will drive demand significantly. The semiconductor industry, currently receiving government support, could experience a 10-12% increase in membrane usage in its early years due to the demand for ultrapure water in manufacturing. For example a 5 GW solar wafer facility will require around 9-10 million liters of water daily, that may eventually require to use large quantities of membranes. While the chemicals and biotech industries are expanding, they may contribute to a modest 5-6% increase in membrane usage, and this can increase many fold, once the monitoring and compliance to PCB norms are tightened, and industries are encouraged to reduce or recycle their effluents. However, the semiconductor sector could see a substantial rise of 10 to 12% in membrane usage over its initial five years.

Many foreign manufacturers are establishing facilities in India, bringing sustainability goals that drive the industry to adopt water recycling and reduce resource usage. One of the world's largest semiconductor manufacturers, is setting up a facility in Ahmedabad and are using brands which are imported from their parent country. These developments could create a significant market for replacement of membranes in the future for Indian companies.

How has Permionics navigated the challenges and opportunities in the Indian membrane technology market?

When I reflect on Permionics' journey, I'm reminded of my father's unwavering determination to introduce membrane technology to India. It was 1976, and he, a hydraulic engineer from the UK working in the chemical industry, envisioned developing the first indigenous RO membrane in India. Despite scarce imports and excruciating wait times, he established a small R&D facility and began experimenting with locally available raw materials, except for the polymer, which wasn't produced in India at the time.

The early years posed challenges, but with support from the local government in Gujarat, we successfully installed nearly 27 RO plants in the state using our in-house developed membranes. As time went on, the landscape began to change.

The US led the charge in membrane technology R&D, introducing new, more efficient TFC and polyamide RO membranes. Suddenly, we faced stiff competition from foreign players flooding the Indian market with advanced technologies and established brands.

While we had developed our own ecosystem for industry-specific applications, we recognized the need to integrate foreign membranes into our systems, but also continued to ensure indigenous manufacturing of membranes We strategically decided to establish a boutique facility to produce membranes similar to those offered by international players. This decision proved advantageous, allowing us to maintain competitiveness in the market while preserving our production capabilities.

As the membranes become more integrated into industrial processes, what are the concerns for the buyers & manufacturers of membrane systems?

Like any other technology, buyers seek both commercial viability and sustainability from membrane system manufacturers and integrators. The biggest challenge in increasing the adoption of membrane technologies in

Solvent recovery membranes processes (Image Courtesy Permionics)

India lies in understanding their limitations. Membranes can last anywhere from 6 months to 5 years depending on usage. In water treatment, they can endure up to 5-6 years with proper operation, but in industries with harsh chemicals, they may require replacement every 6 months. Guarantees typically cover 3 years for water applications but not for wastewater.

Regarding water and wastewater treatment, technology has significantly improved, and costs have decreased. This trend, long established in the US and rapidly growing in China, poses a formidable challenge for Indian companies to match these standards, necessitating accelerated efforts in applied research to produce the same standard of membranes, which have been upgraded and improved of decades of manufacturing and R&D expertise. Another key challenge is finding skilled technicians capable of fine-tuning machinery to local conditions, directly influencing membrane quality. Scaling up is particularly challenging for mid-sized and small companies due to funding constraints and uncertainty about future technology directions.

Tell us company's approach towards R&D and Permionics' electro dialysis process.

At Permionics, our focus is on developing membrane systems using local materials and alternative processes to provide cost-effective solutions. For instance, our research in electro-chemical desalination utilizes cheaper local materials to potentially outperform traditional RO membranes in both performance and cost efficiency. In wastewater recycling, these membranes reduce the dependency on RO membranes by 50%, boasting of greater energy efficiency, operating at lower pressures, , offering a robust, all-in-one solution that integrate multiple steps into one comprehensive unit operation. Further, we've successfully produced value-added compounds from salt solutions, offering a sustainable approach to resource recovery with a potential attractive return on investment .

Our approach includes collaborations with academic institutions, support research projects which are aligned with our needs, ensuring a strong foundation of knowledge and accelerating the commercialization of new technologies. Our initiatives in Electro membranes and Ionomer membranes underscore our commitment to fostering a research ecosystem that bridges academia and industry, facilitating the rapid adoption of promising technologies. We are actively working towards scaling these innovations to benefit a broader range of industries.

Additionally, we are currently developing membranes for hydrogen electrolyzers in alignment with our country's Hydrogen Mission. However, as a private entity, we regret that we are unable to access government funding support.

What is your view on the role of government in terms of policy reforms & support towards applied research to catalyze development of indigenous technology?

First and foremost, I believe that the government should support enabling industries through policy reforms to encourage manufacturers to develop supply chains and reduce import dependence. For example, the government is offering Production Linked Incentives (PLIs) to develop the semiconductor industry, which relies heavily on ultrapure water. In my view, the government should also extend support industries which are offering solutions and or components essential in the production process of semiconductors, wafers, electrolyzers etc. Membranes being one of the key components, its development and indigenization should be also supported/subsidized. This approach ensures that critical components of the semiconductor supply chain receive the necessary backing to maintain high standards and global competitiveness.

Second, the ongoing lack of funding for industry-led research and development has hindered the growth of a robust domestic membrane technology sector in India. Streamlining funding mechanisms to directly support industrial R&D initiatives focused on applied research will accelerate the development and deployment of indigenous technologies. These are crucial for achieving technological self-reliance in membrane manufacturing.

Developing a robust indigenous membrane industry necessitates continuous research and development using locally available raw materials. This requires significant funding and resources, which cannot be passed on to product costs alone. It calls for collaborative efforts among the government, industry, and academia—from basic research on locally available raw materials to pilot studies proving concepts and commercializing technologies.

While the Indian government does support academic research, there is currently no provision for direct funding of industry research, a gap that needs addressing. Similar to China, USA, Singapore, where the governments have established an R&D ecosystem and pilot plants for applied research in new chemistries and processes, India could benefit from creating testing grounds to optimize membrane technology for local conditions and requirements.

Walk us through the market position of Permionics & future growth plans.

We are uniquely positioned in both the Indian and global membrane technology markets, boasting nearly 10,000 installations and over 46 years of industry expertise. Permionics stands out as one of the few vertically integrated providers, combining membrane manufacturing with system solutions. This integration enables us to innovate and adapt swiftly, leveraging close collaborations with academia to develop scalable membrane processes.

Looking ahead, we are focused on expanding our manufacturing capacity and exploring partnerships to scale up our membrane sheet and element manufacturing plant to meet the increasing market demands. Alongside scaling our production capabilities, we are actively investing in advanced membrane technologies for hydrogen electrolyzers and fuel cells.

Our international presence in California facilitates partnerships with startups and universities, enabling us to efficiently identify and commercialize cutting-edge technologies. Through strategic investments in research, development, and manufacturing infrastructure, we aim to strengthen our position as an industry leader. We are committed to pioneering innovations that enhance efficiency and promote environmental sustainability.

With this proactive approach, we are dedicated to maintaining our leadership in the membrane technology market and delivering impactful solutions to meet the evolving needs of industries worldwide. ■

"Smart manufacturing not merely a trend; it is a seismic shift"

In India, the smart manufacturing market is projected to grow at a CAGR of 12.87% from 2022 to 2027, driven by initiatives like "Make in India" and the increasing adoption of Industry 4.0 practices. **Anil Parab, Whole-Time Director & Sr. Executive Vice President (Heavy Engineering & L&T Valves) Larsen & Toubro**, pans out the transformative impact of smart manufacturing technologies. Highlighting case studies of IoT-enabled cranes and automated rolling machines, he demonstrates how these innovations enhance efficiency, safety, and sustainability in industrial operations.

In recent years, smart manufacturing has emerged as a game-changer for the industrial sector. Leveraging cutting-edge technologies, data analytics, and automation, smart manufacturing optimizes production processes, enhances efficiency, and ensures better quality. Our world is evolving at an unprecedented pace, and at the core of this evolution lies the dynamic fusion of technology and industry. Smart manufacturing technologies encompass a range of advanced tools and systems designed to enhance efficiency and productivity in the manufacturing sector. Key technologies include the Internet of Things (IoT) for interconnected devices, artificial intelligence (AI) for predictive analytics and decision-making, robotics for automation, additive manufacturing (3D printing) for rapid prototyping and customization, and Augmented Reality (AR), Virtual Reality (VR) and digital twins for immersing the users in an experience and precise virtual modelling of physical assets.

The emergence of high-speed internet networks and cloud technology has revolutionized industries by enabling real-time data access and seamless collaboration. These advancements improve process optimization, facilitate real-time data collection and analysis, and enhance communication across the manufacturing ecosystem. By integrating these innovations, smart manufacturing creates more agile, responsive, and sustainable production environments, driving both operational excellence and competitive advantage.

Let's dive into some captivating case studies with the key components of smart manufacturing and their impact on the industry.

IoT Enabled Smart Crane : Cranes are indispensable machines in various industrial applications, especially where safety is a paramount concern. However, conventional cranes with analogue hard logic wiring have many limitations and challenges in terms of operation and maintenance.

Some of the challenges are:

- They are prone to errors, faults, and malfunctions that can compromise the safety and efficiency of the work. For example, a faulty wire or a loose connection can cause the crane to lose control or stop working unexpectedly.
- They are difficult to troubleshoot and repair, requiring skilled technicians and costly downtime. For example, finding and fixing the source of a problem can take hours, during which the crane can't be used.

- They are not flexible or adaptable to changing requirements or conditions. For example, they cannot be easily rewired or modified to perform different tasks or functions.

To overcome these issues, a PLC-based control system has been developed for cranes that enhances operational redundancy and facilitates easy troubleshooting. Our PLC-based control system allows us to monitor and control the crane parameters through a user-friendly Human-Machine Interface (HMI) that displays the status and feedback of the crane operations. Moreover, a two-factor authentication mechanism have been implemented for each operation of the machine, ensuring that only authorized and verified commands are executed. This mechanism cross checks each command in all possible manner before initiating any operation. This way, we can prevent unauthorized or accidental operations that can endanger the safety of the people and the equipment. Furthermore, a Server-based application has been designed on the intranet that allows remote access to any crane information without physical presence on crane. This application enables us to view and analyse the data collected by the PLC and the HMI, such as the crane speed, load, temperature, etc. We can also perform diagnostics and troubleshooting remotely, reducing the need for physical inspection and maintenance. The Server-based application provides a graphical user interface that displays the status, parameters, and alarms of each crane, as well as allowing the maintenance team to identify faults of cranes from a distance.

Outcome

The project contributes to the advancement of crane technology and demonstrates the benefits of PLC-based control systems for industrial applications. One of the main benefits is the reduction in breakdown time, as the PLC system can detect and diagnose faults faster and more accurately by eliminating hard and complex wiring than the analog system, it can also alert the maintenance staff via email notifications for any abnormalities. Another benefit is the improvement in safety, as the two-factor authentication and the remote monitoring prevent unauthorized or unsafe operation of the cranes and reduce the exposure of workers to hazardous environments.

By upgrading the crane control system, we have improved the operational efficiency and safety of the cranes. This has resulted in significant savings in maintenance repair cost and manhours. We have reduced the maintenance repair cost by ~50%, which means we need fewer spare parts and materials to

The emergence of high-speed internet networks and cloud technology has revolutionized industries by enabling real-time data access, seamless collaboration, improved process optimization, and enhanced communication across the manufacturing ecosystem

keep the cranes running smoothly. These savings are beneficial for our industry and our customers, as they enhance our productivity and profitability.

Rolling Machine : The Rolling machine, a cornerstone of L&T Heavy Engineering's manufacturing process since 1988, is often referred to as the "heart of Hazira" due to its exceptional performance and capabilities. Despite the absence of original equipment manufacturer (OEM) support, the machine continues to operate using entirely analogue systems and traditional hardwired logic. Its four primary hydraulic pumps operate on a conventional starter logic system. This setup is not only energy-intensive but also results in a substantial no-load running current of approximately 250 amps. The reliance on analogue controls has further compounded inefficiencies, leading to frequent malfunctions. On one occasion, these issues culminated in a prolonged three-month period of inactivity, causing all resources to remain idle and significantly hampering productivity.

To reduce breakdowns and enhance quality, we integrated the machine with new PLC and SCADA systems for full-scale automation. Various sensors, including motor bearing temperature and motor power meters, were installed to monitor real-time temperature and power, sending alerts when limits were exceeded. Maintenance data analysis was conducted to calculate mean time before failure vs mean time to repair. The dashboard now displays the oil temperature and level of the hydraulic tank, along with machine uptime and error logs. Additionally, activities such as cable management and optimizing space for panel and size of exhaust chimney that is used for better air circulation were changed & maintained properly.

Outcome : As a result, breakdown issues have significantly decreased. Utilization improved to 5147 hours (23 cycles), energy savings increased by approximately 2.88 lakh kWh, and tCO2 emissions were reduced by around 236 tonnes.

Smart manufacturing is not merely a trend; it is a seismic shift, a digital revolution reshaping the very essence of how we conceive, create, and deliver goods across the globe. By embracing these innovations, manufacturers position themselves for success in an increasingly competitive global market. However, it is crucial to consider how comfortably organizations would tap this potential of smart manufacturing given the competitive market scenario. ■

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Ion Exchange Resins: Solutions for a Wide Range of Challenges

A large selection of ion exchange resins is available today for a constantly growing variety of applications. In order to choose the appropriate resin for a specific application, it is important to carefully evaluate the range of resin and process properties and parameters. **Stefan Hilger, Manager Global Technical Marketing, Business Unit Liquid Purification Technologies, Lanxess Deutschland GmbH, Cologne, German,** highlights the need for continuous advancements aiming at enhancing sustainability and expanding applications thus, promising future innovations.

Various inorganic and organic materials of both natural and synthetic origin, among them clays, peat, zeolites or metal silicates, are prone of exchanging bound ions with other ions from a surrounding liquid phase. This has been known and used already in ancient times and is already mentioned in the Old Testament.

In this paper, however, the focus will be on ion exchange (IEX) resins, i.e. functionalized organic polymers. In the early days, these were mainly phenol-formaldehyde polymers but today IEX resins are most importantly derived from vinylbenzenes or acrylates. Besides ion exchange, some of these materials are also able to function as absorber for uncharged, polar and even nonpolar molecules, which further widens the application opportunities. Four main types of IEX resins have been developed over time. They are categorized as strong and weak acid cation exchange resins (SAC/WAC) on one hand and strong and weak basic anion exchange resins (SBA/WBA) on the other hand.

Since they were first produced back in the late 1930s in Wolfen, Saxony-Anhalt, Germany, polystyrene-based IEX resins have been employed in a variety of applications. Softening and demineralization of water have been of focal importance for decades and still play a major role, not only for industrial applications, e. g. in power plant cooling circuits, for the preparation of ultrapure water for use in medical applications and in the food, beverage and semiconductor industry, but also for municipal water treatment and household use.

IEX resins based on polystyrene and polyacrylates account for the great majority of products on the global markets today. For industrial applications, polystyrene-based resins are often favored due to their better stability, leading to longer service life. These resins can handle high and also variable flow rates as well as acids and bases in fairly high concentrations.

Competing Technologies

Even for demineralisation, quite a few technologies are available today besides ion exchange. Reverse osmosis (RO), for example, can also remove dissolved ionic substances quite efficiently. The membranes employed, however, are frequently susceptible to fouling and can have difficulties when dealing with variable flow rates. Very low ion concentrations in permeates can only be achieved with difficulties at the price of repeated, energy-consuming treatment.

Electrodeionization (EDI), as another example, requires a relatively high energy input and also has difficulties in obtaining water resistivity above 16 M⍰, as is required for ultra pure water. Especially silica is difficult to remove in one single step. EDI systems generally have a very low tolerance for hardness ions and organic matter due to blocking of the membranes. Furthermore, maintenance and replacement cannot easily be split into a device and an active component as is possible with an IEX system.

In contrast to IEX with resins which can be tailored to be highly selective (see below), both RO and EDI

exhibit only very limited ion selectivity, if any. Therefore, both the latter methods can only remove the dissolved ion contents as a whole. In all these respects, an IEX resin system exhibits superior properties which make it favorable whenever one or more of the requirements mentioned above are crucial.

However, IEX resins also have their limitations. Although the stability against oxidative stress is significantly better with IEX compared to RO and EDI, oxidizing agents may markedly limit the service life especially of anion exchange resins. Due to their polymeric backbone, operating temperatures for most types of polystyrene-based resins are limited to approx. 140 °C (SAC/WAC) and 70 °C (SBA/WBA, chloride form) or 40-45 °C (SBA/WBA, OH form). SBA and WBA resins on acrylate basis are more sensitive to elevated temperatures. Even in chloride form they should not be employed at temperatures above 40 °C.

Capabilities of IEX Resins

Besides from the aforementioned four functionalization classes of IEX resins, additional subclasses can be identified which either contain special functional groups, e. g. bi- or polydentate groups which are capable of forming chelating complexes with enhanced selectivity. Additionally, certain resins may also allow for non-ionic interactions with substrates, thus establishing co-operative binding modes (Figure 1).

Selectivity for Divalent versus Monovalent Ions

A key property of modern IEX resins is their selectivity which goes far beyond that simply for anions or cations in general. Resins can easily discriminate between monovalent and divalent ions, for example, due to a markedly different binding strength. These differences in selectivity usually increase with a higher degree of cross-linking, i.e. a higher share of divinylbenzene added as cross-linking agent during polymerization, as shown in Table 1.

	Selectivity Coefficient			
DVB	**4%**	**8%**	**12%**	**16%**
H^+	1	1	1	1
Na^+	1,3	1,5	1,7	1,9
NH_4^+	1,6	1,95	2,3	2,5
Mg^{2+}	2,4	2,5	2,6	2,8
Ca^{2+}	3,4	3,9	4,6	5,8
Sr^{2+}	3,85	4,95	6,25	8,1
Ba^{2+}	6,15	8,7	11,6	16,5

Table 1. Relative selectivity coefficients (H+ = 1) of SAC resins as a function of the degree of cross-linking

For trivalent ions, selectivity differences may be even more pronounced. Special IEX resins with small bead size and very fast kinetics therefore even a partial separation of rare earth ions, namely of lanthanum, cerium, praseodymium and neodymium, from other rare earth, earth alkali and aluminum ions is possible. Separations of this kind are considered to be the most difficult of all.

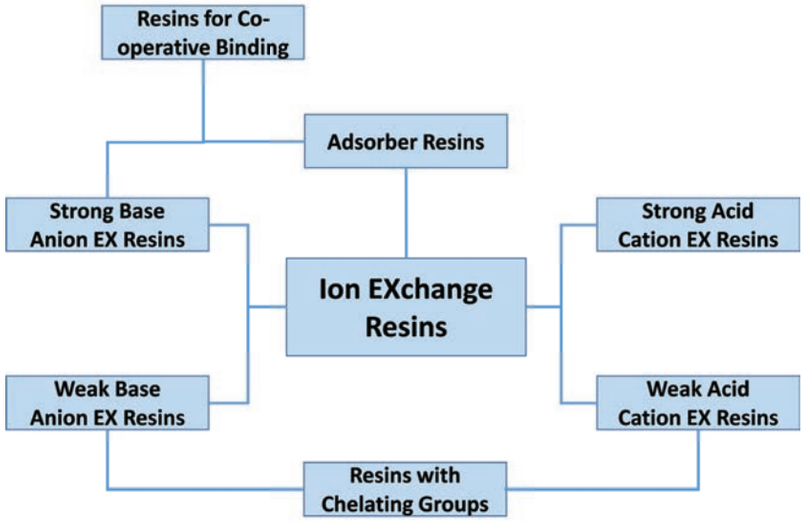

Figure 1. Classes and subclasses of ion exchange resins

Selectivity for Specific Ions

Even more, appropriately functionalized resins can even be tailored to preferentially bind a specific ion, allowing for a partial or even almost complete separation of mixtures. Most often, this selectivity is due to chelating functional groups, i.e. ionic or polar groups which can establish more than one (ionic) contact to the substrate ion in the course of complexation (Figure 2).

As an example, the removal of calcium and magnesium ions is possible even from concentrated brine using a special SAC resin with small beads. The

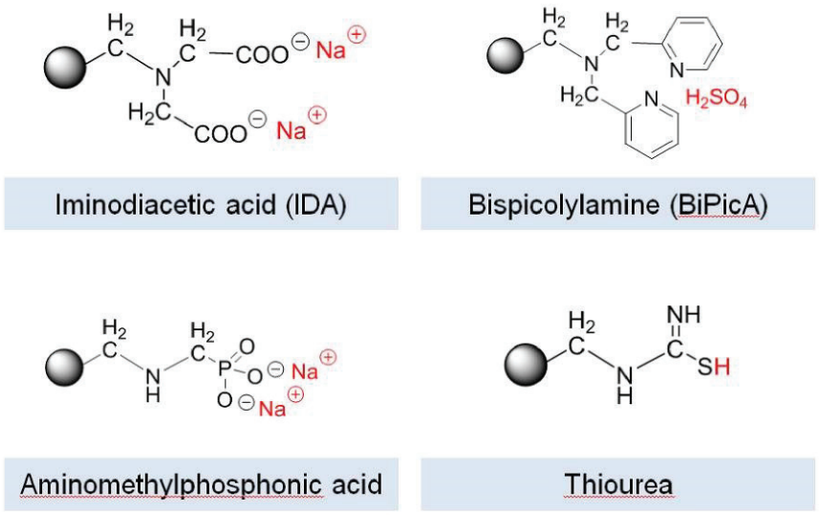

Figure 2. Overview of specialized IEX resins by functional group

absence of earth alkali cations is a crucial requirement in chlor-alkali electrolysis in order to prevent blocking of the cell membranes and enhance the efficiency of the electrolysis. The concentration of these divalent ions needs to be reduced down to the single-digit ppb range for this purpose. In a similar process, calcium in a wide concentration range can also be separated from lithium brine by ion exchange during the production of battery-grade lithium salts. Even lithium itself can be recovered in the form of lithium aluminates from brine with special resins which have been modified with aluminum salts.

Selective binding of ions can also be a solution for medical treatment, as exemplified by IEX resins that – after oral administration – selectively bind potassium ions and can thus be used to treat hyperkalemia. The resin binds potassium in the digestive tract and is then excreted in a loaded form. Further medical applications include the controlled release of active pharmaceutical ingredients over an extended period of time. IEX resins can also be employed as excipients in medical formulations, e. g. as taste masking agent in orally administered drugs containing for instance antibiotics with a bitter taste or nicotine for smoking cessation. The mechanism involves the drug being initially bound to the resin. The complexation retains structural integrity in the neutral oral environment. Under the acidic environment in the stomach, the medicine is then released from the resin after being replaced by protons.

An application which has gained substantial interest recently in the course of the fight against climate change is "Direct Air Capture" (DAC) of carbon dioxide facilitated by SBA or WBA resins. This is one of several carbon capture and storage (CCS) technologies which have been proposed and implemented to reduce carbon dioxide emissions from point sources.

Binding by Means of Hydrophobic Interactions

Additionally, IEX resins can even bind uncharged molecules by adsorption. This is due to weak polar interactions and can, for example, be employed to separate micro-pollutants containing aromatic rings such as active pharmaceutical ingredients, pesticides or non-ionic detergents (Figure 3) during municipal waste water treatment. The IEX resin is more efficient than activated carbon with high loading capacity, high mechanical stability and exhibits fast exchange kinetics which allows the use of small, compact filters instead of large columns.

Co-operative binding situations can also occur. In such cases, a substrate molecule is simultaneously bound to the IEX resin by means of ionic and hydrophobic interactions (Figure 4). Such a behavior is observed during removal of long-chain PFAS (per- and polyfluoroalkyl substances), e. g. perfluorononanoic acid (PFNA) from waste water. PFAS molecules usually consist of a polar "head" (carboxylic acid) and a nonpolar "tail" (per- or polyfluorinated carbon chain). While the former is bound to the IEX resin via coulomb attraction, the latter establishes weak interactions with aromatic π-electron systems of the polystyrene backbone of the resin.

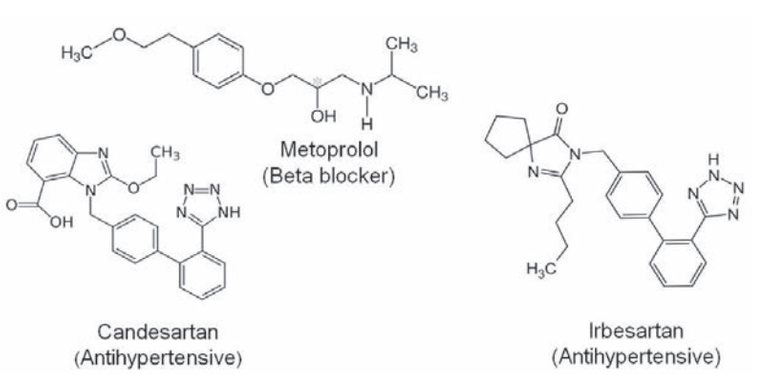

Figure 3.Typical micropollutants which can be removed by interaction with IEX resins

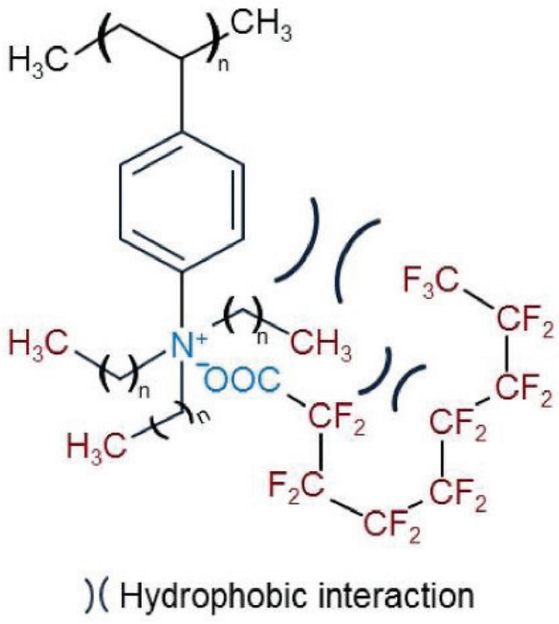

Figure 4. Co-operative binding of a long-chain PFAS molecule (PFNA, perfluorononanoic acid) to a polystyrene-based SBA

Important Selection Parameters for IEX Resins

Even if there are many characteristics that determine which resin is best suited for a particular application, some basic parameters will be discussed here due to their general importance, namely uniformity, morphology, bead size and the life-cycle sequence.

Uniformity

For more than four decades now, specialized polymerization processes are available for the production of resins of uniform particle size (mono¬dispersed resins). These resins offer significant advantages over heterodispersed products:

- Less fine and less coarse beads leading to less ion leakage and better regeneration performance
- Higher operating capacity due to more uniform flow over the surface and less tendency to channel formation
- Lower pressure drop due to the existence of evenly wide, unblocked channels between the beads to enable high flow rates
- Higher mechanical stability due to homogeneous, optimized functionalization – longer service life, less generation of fines which would increase the pressure drop
- Higher osmotic shock stability – especially important for macroporous chelating resins, for example when a chelating resin loaded with calcium as obtained from brine polishing for chlor-alkali electrolysis (see above) is regenerated with hydrochloric acid and afterwards conditioned with caustic soda solution. The latter causes osmotic stress resulting from a 60 % increase in volume.

Today, most of the monodispersed resins are based on polystyrene as polymeric backbone. Polyacrylate resins are mostly heterodispersed due to the lack of an economically feasible production process. However, membrane emulsification processes were developed in recent years for this purpose. Currently, most acrylate resins belong to the WAC class of resins, where this is not of crucial importance.

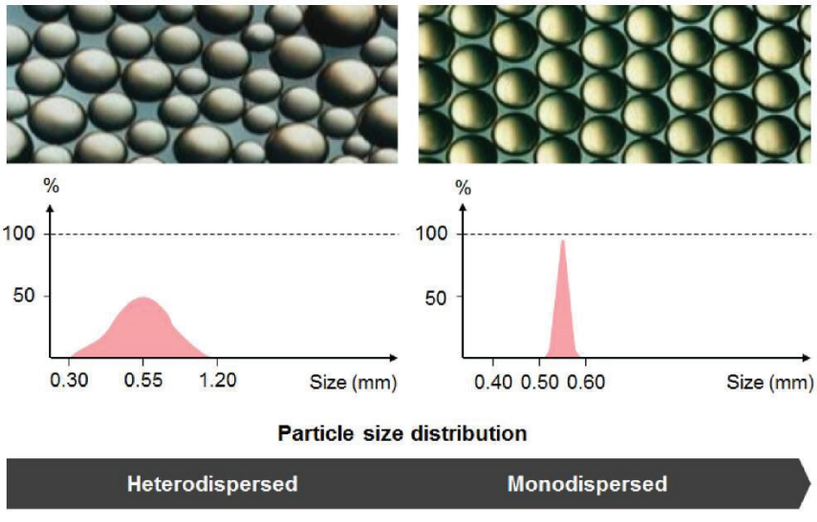

Figure 5. Particle size distribution in hetero- and monodispersed resins

Morphology

Basically, two types of resin can be distinguished in terms of morphology (Figure 6). In gel-type or microporous resins, on one hand, the bead surface is covered by a gel layer containing the functional groups which are easily available for ion exchange. The micropores are usually less than 2 nm in diameter. Gel-type resins exhibit high operative capacities. Typical applications include acid-catalyzed reactions with gel-type SAC resins such as dehydrations, (co-)

condensations, esterifications and Friedel-Crafts-type alkylations. However, their surface is sensitive to fouling, induced e. g. by NOM (natural organic matter), which makes access to the functional groups more difficult.

In macroporous resins, on the other hand, not only the bead surface, but also wide channels of more than 50 nm in diameter within the bead are equipped with functional groups. This leads to a markedly increased active surface and enhanced mechanical stability of the beads. Because of their high mechanical and osmotic stability, they are employed in a variety of processes including those in non-aqueous solvents, e. g. for binding heavy metal ions. Whenever a high total capacity and therefore a high degree of cross-linking is required and at the same time stable resins are needed, there is no way around macroporous resins. Even relatively large contaminant molecules such as NOM (Natural Organic Matter) can be adsorbed in the pores and are subsequently liberated during regeneration.

Macroporous, strongly basic anion exchange resins based on a cross-linked polyacrylate can be tailored to exhibit a special pore structure and resin matrix. They are then ideally suited for the capture of high molecular weight compounds, e. g. for the treatment and purification of products derived from biomass. This means that liquid sugar syrups or complex process solutions such as fermentation broths can be purified and treated. As an example, the naturally occurring glycosaminoglycan polymer heparin which is used to prevent blood coagulation can be extracted and thus purified with such a resin.

Bead Size

The particle size of monodispersed resins can be adjusted with high precision by means of continuous bead formation through a perforated plate. In aqueous suspensions containing monomer droplets of uniform size, the resin beads are then formed by means of polymerization (Figure 7). This method allows beads of different sizes to be created in a flexible and reproducible manner.

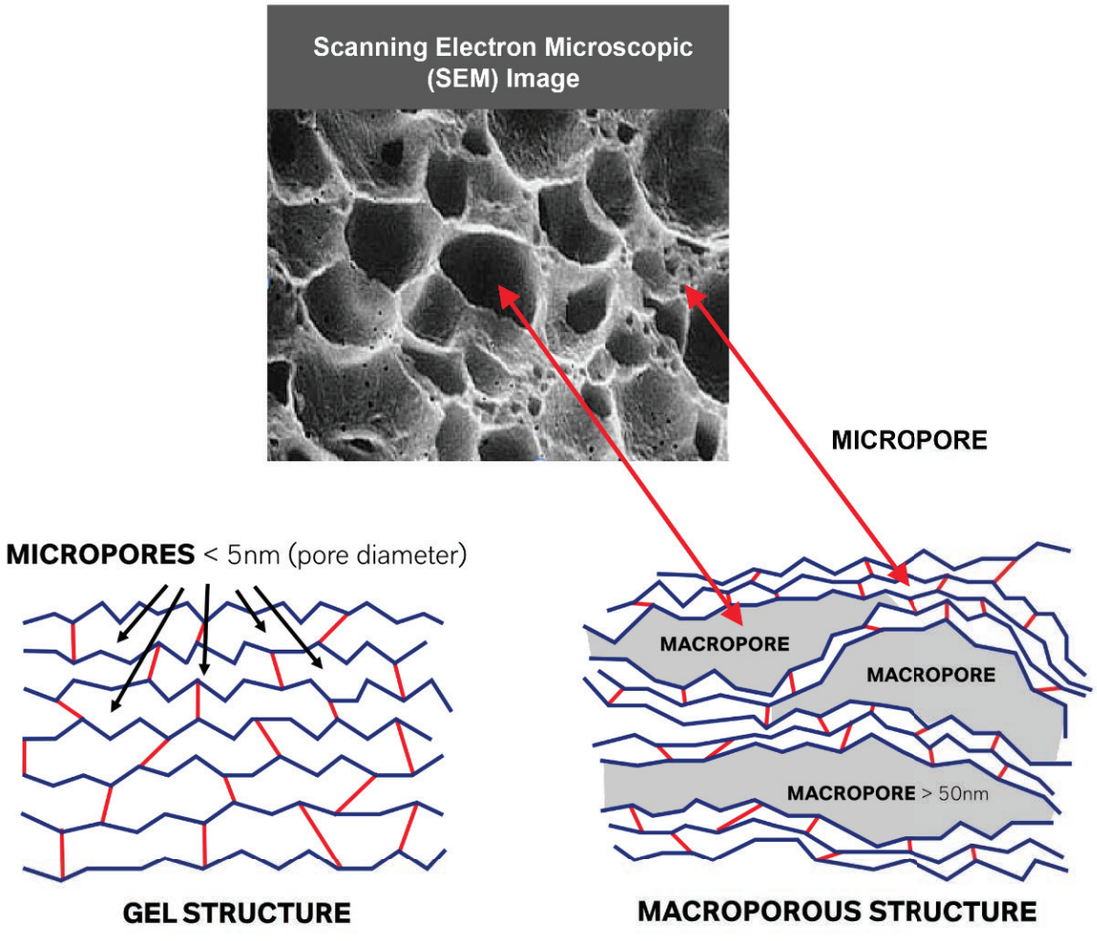

Figure 6. Structural comparison of gel-type and macroporous IEX resins

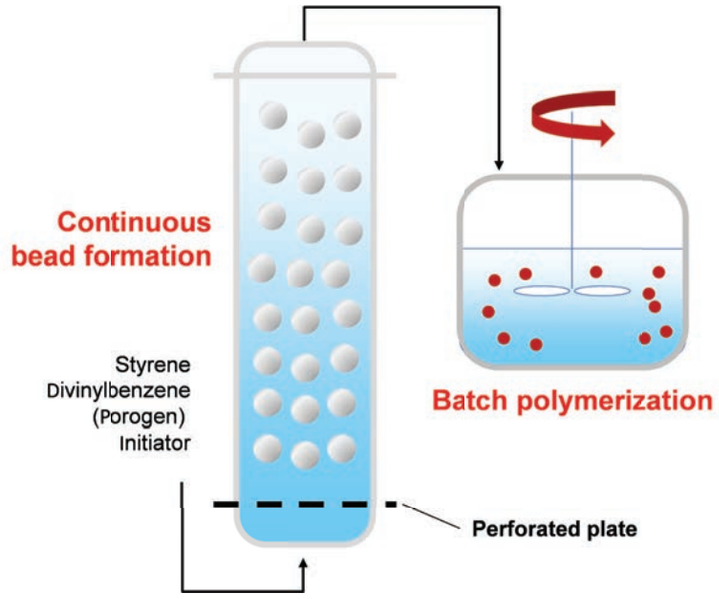

Figure 7. Two-stage production of monodispersed ion exchange resins through continuous bead formation and subsequent batch polymerization

To obtain ultrapure metals – ultimately through electrolytic separation – by means of hydrometallurgy, interfering foreign ions have to be removed right down to the trace level. This presents special requirements regarding selectivity, capacity and exchange speed. The size of the resin beads plays a key role here.

Macroporous resins with a sponge-like structure and a large inner surface area are usually employed here. The polymer beads in standard resin types measure between 0.5 mm and 0.7 mm. In addition to the type of functional groups in the polymer, their suitability for a specific separation task depends on their number and a range of other properties and characteristics. Process parameters such as the pH value, temperature, and flow rate also influence the separation performance.

Small resin beads (monodispersed small, MDS) with a diameter of just 0.3 mm to 0.4 mm exhibit very different properties and characteristics than standard-sized beads. Thanks to their smaller size and, in turn, shorter diffusion paths, they exhibit faster kinetics during exchange and regeneration. Their high packing density makes them ideal for chromatographic separation. They also have higher capacity utilization and, in turn, longer service lives with lower chemical requirements for regeneration. However, the higher packing density also results in greater pressure loss.

A comparison of the loading performance (Figure 8) of an iminodiacetic acid (IDA) chelating resin with MDS beads (left) with copper ions (blue) shows clear differences with respect to standard monodispersed resin (MD, middle) and heterodispersed resin (HD, right) with a wider grain size distribution. In addition to superior retention, the MDS resin exhibits a sharp, precisely defined limit zone of adsorption. This prevents a premature breakthrough observed especially with HD resin.

These beneficial properties can be leveraged for various tasks such as lithium brine purification where small-size beads significantly reduce calcium. Ultrapure lithium brine obtained in this way is needed mainly for electrolysis in order to protect cell membranes from scale precipitation.

The “resin in pulp” (RIP) process imposes quite different requirements with respect to bead size. In such a process, an ion-containing suspension of ore slurry is initially mixed with the resin beads. After a contact period during which the resin absorbs the ions, the resin is separated again. To increase efficiency, multiple vessels are positioned in a

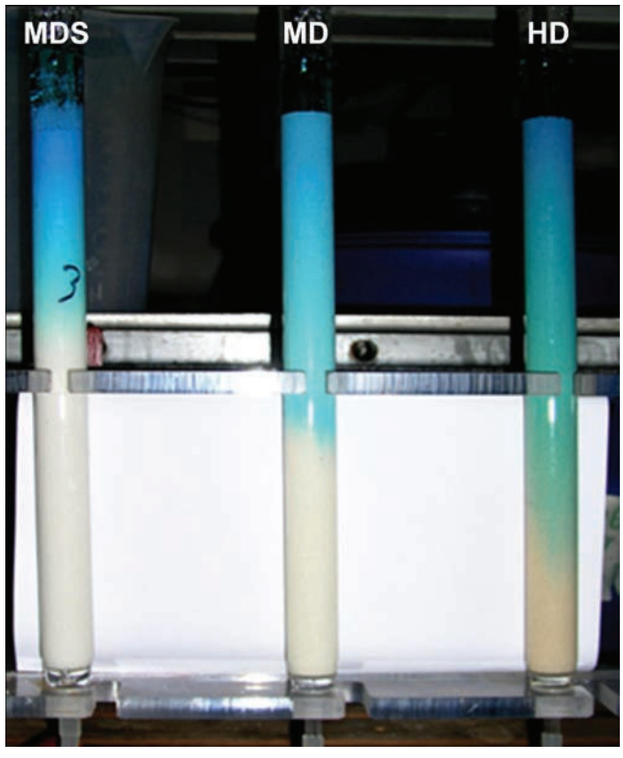

Figure 8. Loading performance of MDS, MD, and HD cation exchange resins with copper ions under identical reaction conditions

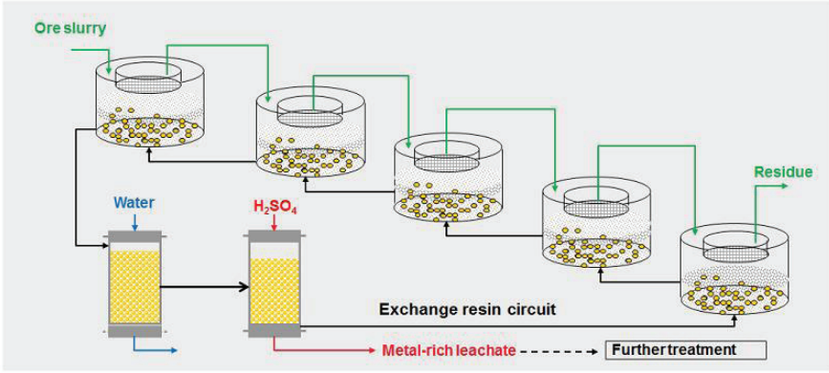

Figure 9. Schematic representation of a continuous "resin in pulp" (cRIP) process

cascade arrangement, and the ore suspension is treated with the exchange resin in counterflow (continuous RIP, Figure 9). The RIP process is a useful alternative to fixed bed ion exchange in columns which is particularly advantageous when the substrate is a suspension or dispersion instead of a clear solution.

During this process, the majority of metal ions from the slurry is bound to the resin and can be separated from this when the resin is regenerated. In the field of hydrometallurgy, ion exchange processes such as these are increasingly replacing the decanting of suspensions in large water tanks because this not only requires a great deal of space, but is also extremely time- and cost-intensive.

Mechanically robust ion exchangers are needed for separating and transferring the resin as efficiently as possible. This helps prevent premature resin breakage during extraction. A sufficient size difference between resin and ore slurry particles is also essential for efficient separation. Because of this, monodispersed resins with a larger particle diameter of 0.85 mm (XL) and heterodispersed resins with an even larger average particle diameter of 1.1 mm (± 0.1, XXL) have been developed

Life-cycle Sequence

The ability to be regenerated is a key advantage of IEX resins over other materials which can just acts as adsorbers and have to be disposed of after single use. In most cases, e. g. when employed in softening or demineralization of water, in the preparation of makeup water or in condensate polishing in industrial water-steam circuits, IEX resins can be regenerated many times, resulting in a service life of several years.

There are, however, applications where regeneration may be inefficient or even disadvantageous. The former could be true in cases where the resin quantities employed are small and no on-site regeneration systems are available. If external regeneration is feasible, it should be decided on according to economic standards. Regeneration is usually also omitted in cases where only trace amounts of ions are removed from large volumes and the service life of the resin is therefore extremely long. This might be true for final polishing mixed-bed IEX systems in the production of ultrapure water. In this case, the original quality of the delivery form can no longer be restored, at least on site. For economic reasons, it therefore does not make sense to set up and maintain a regeneration unit.

Regeneration may be disadvantageous when hazardous contaminants are bound to the IEX resin so that a significant concentration, i.e. volume reduction, of the hazardous waste has already taken place. If then the resin would be regenerated, a relatively small volume of resin would give rise to a larger volume of contaminated regeneration and washing solutions, which would have to be disposed of subsequently. This might for example be the case for resins loaded with mercury from flue gas scrubbing or with those loaded with radioactive cations from nuclear power plants. In addition, such cations are bound very tightly, which would make regeneration impossible or at least not economical.

Innovative regeneration protocols, however, could help to recycle valuable resins even after loading hazardous substances onto them. One example is the regeneration of SBA resins which have been used to trap PFAS. In these cases, regeneration can be achieved by treatment with aqueous methanol containing a small amount of sodium chloride. After regeneration, the resin can be reused and the methanol can be stripped off the regeneration solution, leaving behind only a very small amount of PFAS, salt and water.

Outlook

Although the basic principles of ion exchange facilitated by resins are known for more than a century now, the development is still ongoing. Improvements in selectivity, capacity and stability have been achieved over time and are likely to continue in the future. Not the

least, future development will also be triggered by newly emerging, challenging fields of application. Improved recycling methods for spent battery materials, catalytic processes for the circular economy or advanced biomedical applications could be conceivable options. The industrial production of the first Acrylate- and polystyrene-based resins from renewable feedstock or recyclates can be considered a milestone on the path to improved sustainability. The first representatives of this class of sustainable resins have just become available, not only in lab or pilot quantities, but on an industrial scale. ■

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Current market trends in the chemical industry and future prospects

The Indian chemicals industry, is set for remarkable growth, with projections reaching USD 1 trillion by 2040. However, this optimistic future is tempered by challenges including global economic fluctuations and supply chain disruptions. **Prashant Vasisht, Senior Vice President and Co-Group Head - Corporate Ratings, ICRA Ltd.,** explores the industry's growth drivers, competitive landscape, and strategic initiatives shaping its future.

Overview of the Indian Chemicals Industry

The chemicals industry in India produces more than 80,000 products, with an estimated industry size of USD 233 billion in FY2022. The industry is expected to grow at a healthy CAGR of ~9% to USD 304 billion by 2025 and USD 1 trillion by 2040, driven by rising demand in the end-user segments and exports. However, it faces multiple near and long-term challenges. In the past two years, demand for chemicals was sluggish owing to high inflation and recession in Europe, inflation in the United States, and a weaker-than-expected rebound in Chinese demand. In addition, over-ordering after Covid-19 in CY2021 and CY2022 resulted in high inventory levels, leading to prolonged destocking amid a weak global economic scenario.

Global Economic and Supply Chain Challenges

The specialty segment is the strongest pillar of the Indian chemical sector, however, most domestic companies have a long way to go, as their R&D expenses as a proportion of sales remain low compared to international companies. They spend less than 1% of their net sales on R&D compared to 7-9% by some large MNCs and 3-5% by several Chinese companies.

According to the IMF, the global economy is expected to grow at 3.2% in CY2024 and CY2025, the same as CY2023, pointing to only a modest rebound in chemical demand. Destocking transitions to restocking for many chemicals, but the underlying weakness in demand and overcapacity for some products will likely continue. Some segments like dyes and pigments, which cater to discretionary end-use industries like textiles, have been more severely impacted than others.

Supply chain disruptions became pervasive during the Covid-19 pandemic. Initially, the Indian chemicals industry seemed to benefit from the China+1 strategy. However, the euphoria was short-lived as China came back into the markets with a vengeance post the lifting of its zero-Covid restrictions in December 2022. Chinese production for chemicals surged, leading to a sharp drop in prices, intense competition for Indian manufacturers, and accusations of aggressive dumping by several countries. Additionally, China continues to add huge capacities for several chemicals, leading to an over-capacity scenario amid an overall sluggish demand.

Domestic and International Competitive Landscape

Another important trend is the impact of high gas prices on the European chemical industry, leading to cost and demand pressures. The current gas prices are at least 50% above historical levels (CY2014-CY2019) and are about 3.9x higher than in the US. Chemical producers in Europe may migrate to the US and the Middle East, where crude oil, natural gas, and naphtha are available in abundance, rather than India, where crude oil and natural gas import dependence is high. Accordingly, the US and the Middle East could see large capacity additions owing to the availability of cheaper natural gas.

Infrastructure is also a challenge in India, with only four Petroleum, Chemical and Petrochemical Investment Regions (PCPIRs) against 250 chemical parks in China and 10 each in South Korea and Thailand. Additionally, other Asian countries such as Malaysia, Indonesia, South Korea, and Thailand offer better fiscal packages than India. Indian companies also lack the economies of scale and diversification of products of some of their international counterparts. For example, the country lacks BASF-type Verbund sites with investment of USD 9-10 billion at a single site or the crude oil-to-chemical complexes with investments of USD 15-20 billion, of which China has 4-5.

Future Prospects and Strategic Initiatives

New climate-related policies have also been impacting the global chemical landscape. The US enacted 'The Infrastructure Investment and Jobs Act' in 2021 and followed it up in 2022 with the 'Creating Helpful Incentives to Produce Semiconductors and Science Act' and the 'Inflation Reduction Act', which infused enormous capital for domestic manufacturing of electric vehicle infrastructure, clean energy, etc. In February 2023, Europe announced the Green Deal Industrial Plan to prevent an exodus of industrial activity from Europe. Additionally, the Cross Border Adjustment Mechanism (CBAM) was adopted in May 2023 to help level the playing field between the European Union and foreign producers by putting a carbon price on certain carbon-intensive products.

The specialty segment is the strongest pillar of the Indian chemical sector, however, most domestic companies have a long way to go, as their R&D expenses as a proportion of sales remain low compared to international companies. They spend less than 1% of their net sales on R&D compared to 7-9% by some large MNCs and 3-5% by several Chinese companies.

The specialty segment is the strongest pillar of the Indian chemical sector where quality, service, customization, and technical support are used to offset competition and charge premiums. However, most domestic companies have a long way to go, as their R&D expenses as a proportion of sales remain low compared to international companies. They spend less than 1% of their net sales on R&D compared to 7-9% by some large MNCs and 3-5% by several Chinese companies. Nevertheless, the specialty segment, which contributes 50% to the total chemical exports of the country, has been increasingly focusing on R&D to introduce new products.

Some of the key segments that companies are focusing on are battery chemicals, fluoro-chemicals, electronic chemicals, and green chemicals. While several large capex plans have been announced in these areas, the success of these remains to be seen, especially for sunrise sectors such as battery chemicals where competing technologies vie for supremacy. Additionally, with phones, electronics, and semiconductor manufacturing increasingly moving to India, companies are diversifying into manufacturing electronic and semiconductor chemicals. However, there are a large number of chemicals such as nano-enzymes and nanoparticles where Indian companies have not made any inroads, and these could be future areas of development.

Most Indian companies have historically operated in their niche areas and not in multiple chemistries. India remains highly dependent on China, South Korea, Taiwan, etc., for a large number of chemicals. However, several domestic companies are now focusing on backward integration or import substitution as India imports a large number of basic chemicals, petrochemicals, technical and specialty chemicals. In FY2021, the net imports of chemicals stood at about USD 13 billion, presenting an opportunity for Indian manufacturers to substitute these products.

Government Initiatives

The Department of Chemicals & Petrochemicals intends to bring a production-linked incentive scheme for the chemical sector. A mandatory Bureau of Indian Standards (BIS) certification to maintain the quality of imported chemicals could help regulate imports and promote domestic production of some chemicals. BIS norms have been implemented for several chemicals such as caustic soda, monoethylene glycol, purified terephthalic acid, polyester fibers and are likely to be implemented for many more like polyethylene and polypropylene. Various Government initiatives such as Atmanirbhar Bharat and the National Logistics Policy would also aid in boosting domestic production.

Therefore, the Indian chemicals industry stands at a pivotal point with significant growth potential driven by both domestic and international demand. While facing numerous challenges, strategic initiatives and government policies are set to bolster the sector. Focusing on specialty chemicals, backward integration, and R&D will be crucial for sustaining growth and enhancing global competitiveness. ■

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Innovative Solutions in Water Purification: The Antimicrobials Filter Cartridge (AMFC)

Antimicrobial resistance presents a significant global challenge, straining healthcare systems worldwide. **Pavithra Ravindran, CMO, Biznustek Systems Pvt. Ltd.,** discusses the Antimicrobials Filter Cartridge (AMFC) by BSPL, an innovative water purification technology. The AMFC, designed to target contaminants like antibiotics, advances filtration with versatile applications, eco-friendly materials, and crucial solutions for combating antimicrobial resistance and promoting environmental sustainability.

As global populations grow and industries expand, the demand for clean and safe water becomes even more critical. This urgency drives the need for innovative water purification technologies that not only ensure high standards of water quality but also address emerging contaminants and environmental concerns. One such groundbreaking innovation is the Antimicrobials Filter Cartridge (AMFC) by BSPL, marking a significant advancement in water filtration and separation

Advanced Filtration Technology

The AMFC utilizes cutting-edge filtration technology to selectively target and eliminate a broad spectrum of contaminants, including antibiotics and antimicrobials. Traditional filtration systems, such as Reverse Osmosis (RO), often fail to effectively remove these contaminants due to their molecular size and resistance properties. The AMFC overcomes these limitations through its sophisticated filtration matrix, combining physical, chemical, and biological processes to neutralize antimicrobial contaminants effectively.

Versatile Compatibility

Designed with versatility in mind, the AMFC can be seamlessly integrated into various water treatment systems and appliances, making it suitable for both residential and commercial applications. Whether installed in household water purifiers or large-scale industrial water treatment plants, the AMFC offers a robust solution to ensure the highest levels of water purity and safety.

Sustainability and Eco-Friendliness

In line with global efforts towards sustainability and environmental protection, the AMFC is crafted from eco-friendly materials and manufactured using sustainable processes. Additionally, the cartridge is biodegradable, ensuring minimal environmental impact at the end of its lifecycle. The process underscores responsible environmental stewardship and its role in promoting a healthier planet.

Health and Safety Assurance

One of the most significant advantages of the AMFC is its ability to remove harmful contaminants, such as antibiotics and antimicrobials, which pose severe risks to public health. By effectively eliminating these contaminants, the AMFC ensures that the water consumed is safe and healthy, providing peace of mind to consumers and safeguarding communities against waterborne diseases and antimicrobial resistance (AMR).

Addressing Antimicrobial Resistance

Antimicrobial resistance is a growing global concern, with resistant pathogens posing significant challenges to healthcare systems worldwide. The AMFC plays a crucial role in mitigating the spread of AMR by removing antimicrobial residues from water sources, thus preventing the transmission and proliferation of resistant microorganisms. This proactive approach contributes to global public health efforts to combat AMR and promotes environmental sustainability by reducing the prevalence of these harmful contaminants in water supplies.

Lab-Scale Study Insights

In a meticulously controlled lab-scale study, the Antimicrobial Functionalized Carbon (AMFC) demonstrated exceptional efficacy in adsorbing a comprehensive array of antimicrobials from a simulated solution. The study involved passing 1 liter of the test solution, which contained 22 different antimicrobials, through 100 grams of the AMFC adsorbent mixture housed within a specialized cartridge. Analysis before and after filtration, conducted using LC-MS/MS techniques, revealed an impressive outcome: the AMFC effectively adsorbed over 90% of all 22 test antimicrobials.

The study highlights the AMFC's strong adsorption capacity, efficiently removing diverse antimicrobial contaminants within 10 minutes, crucial for wastewater treatment and mitigating environmental and public health risks.

The results underscored the AMFC's robust adsorption capacity and its ability to handle a diverse spectrum of antimicrobial contaminants within a short contact time of just 10 minutes. This finding is particularly significant in the context of wastewater treatment, where rapid and thorough removal of pharmaceutical residues is critical to mitigating environmental and public health risks. The study's controlled conditions ensured precise measurement and validation of the AMFC's performance, providing valuable insights into its potential application in larger-scale environmental remediation efforts.

Furthermore, the high adsorption efficiency observed across a broad range of antimicrobials highlights the versatility and reliability of the AMFC technology. This capability positions it as a promising solution for addressing complex challenges associated with pharmaceutical contamination in wastewater streams, offering a viable pathway towards sustainable and effective water treatment solutions. Future research and development efforts could further optimize the AMFC's design and operational parameters to

The study highlights the AMFC's strong adsorption capacity, efficiently removing diverse antimicrobial contaminants within 10 minutes, crucial for wastewater treatment and mitigating environmental and public health risks.

maximize its efficacy under varying environmental conditions, reinforcing its role as a potent tool in combating antimicrobial pollution.

Pilot Study Results

The pilot study, spanning six days, served as a crucial step in evaluating the practical efficacy of the Antimicrobial Functionalized Carbon (AMFC) technology within a live environment. Implemented at an Effluent Treatment Plant (ETP) within a hospital, the AMFC prototype demonstrated substantial success in addressing the presence of Ceftriaxone and Tigecycline, two widely used antimicrobial agents. Findings revealed that the AMFC device achieved impressive removal rates, effectively reducing Ceftriaxone levels by approximately 68.8% and Tigecycline by about 90%. These results underscore the device's capability to significantly mitigate antimicrobial contamination in wastewater settings.

Throughout the pilot study, operational conditions such as varying contact times were observed to impact the adsorption rates of the AMFC towards the study's conclusion. Despite these fluctuations, the overall trend consistently showcased the device's robust performance in reducing antimicrobial concentrations. The observed reductions in Ceftriaxone and Tigecycline highlight not only the AMFC's technical proficiency but also its potential applicability in enhancing wastewater treatment processes, particularly in environments where pharmaceutical contaminants pose significant ecological and health concerns.

The study affirmed the AMFC's effectiveness as a viable solution for addressing antimicrobial pollution within hospital wastewater streams. By significantly lowering Ceftriaxone and Tigecycline levels over the experimental period, the device demonstrated promising capabilities in real-world conditions. These findings lay a solid foundation for further development and deployment of the AMFC technology, offering potential pathways to mitigate the environmental impact of pharmaceutical residues discharged from healthcare facilities.

Real-World Applications

The versatility and effectiveness of the AMFC make it an ideal solution for a variety of real-world applications. In industrial settings, the AMFC can be integrated into existing water treatment infrastructures to enhance the removal of antimicrobial contaminants. This is particularly crucial in pharmaceutical manufacturing, hospitals, and agricultural operations where antibiotic use is prevalent. Additionally, municipal water treatment plants can leverage the AMFC to ensure the delivery of safe and clean drinking water to communities, thus improving public health outcomes on a larger scale.

Economic Benefits

Implementing the AMFC (Advanced Multi-Stage Filtration Cartridge) in water treatment systems provides notable economic benefits. By enhancing the efficiency of contaminant removal, the AMFC minimizes the need for frequent maintenance and the replacement of traditional filtration components. This reduction in upkeep requirements translates directly into lower operational costs for users.

Additionally, the superior filtration performance of the AMFC helps in extending the overall lifespan of water treatment systems. This extension in system longevity means that both residential and commercial users can avoid the costs associated with early system replacements. Consequently, the need for fewer replacements and repairs further reduces the financial burden on users.

In the long run, these economic advantages are substantial. For residential users, the cost savings contribute to more affordable and sustainable household water management. For commercial users, the reduced operational and maintenance expenses enhance business profitability and sustainability. Overall, the implementation of AMFC technology supports both immediate and long-term financial efficiency in water treatment practices.

Future Developments

BSPL continues to innovate and refine the AMFC technology to address evolving water purification challenges. The company is committed to ongoing research and development efforts that aim to enhance the filtration capabilities of the cartridge. These efforts focus on improving the efficiency and effectiveness of contaminant removal, ensuring that the AMFC remains at the cutting edge of water purification technology.

In addition to improving filtration performance, BSPL is also working to increase the durability of the AMFC. By making the cartridge more robust, the company aims to extend its lifespan and reduce the need for frequent replacements. This enhancement not only benefits users by lowering operational costs but also contributes to sustainability by reducing waste and the demand for new materials.

Looking ahead, BSPL envisions incorporating smart technologies into future iterations of the AMFC. These advancements may include real-time monitoring and optimization features, allowing for more precise control over the filtration process and quicker responses to changing water quality conditions. By integrating these smart technologies, BSPL aims to further solidify in advanced water filtration solutions, providing users with cutting-edge tools for effective and efficient water purification.

Conclusion

The Antimicrobials Filter Cartridge (AMFC) represents a revolutionary advancement in water purification technology. With its advanced filtration capabilities, versatile compatibility, commitment to sustainability, and significant role in addressing antimicrobial resistance, the AMFC sets a new standard in water treatment solutions. As the world faces increasing challenges related to water quality and environmental sustainability, innovations like the AMFC are crucial in ensuring access to clean, safe, and healthy water for all.

By integrating the AMFC into existing water treatment systems, industries, communities, and households can benefit from enhanced water purity and contribute to the global effort to combat antimicrobial resistance. As we move towards a future where clean water is paramount, the AMFC stands as a beacon of innovation, providing a robust solution to some of the most pressing water purification challenges of our time. ■

Author

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Transforming Industry: Biomimetic CO2 Capture & Mineralization for Sustainable Decarbonization

PIYALI MAJUMDER
Chief Scientific Officer
UrjanovaC Pvt. Ltd.

With global CO2 emissions at critical levels, combating climate change demands innovative solutions. **Piyali Majumder, Chief Scientific Officer, UrjanovaC Pvt. Ltd.,** draws attention to a novel biomimetic technology harnessing catalyst-driven CO2 capture in water, transforming it into valuable carbonate minerals. This scalable, sustainable approach promises a pivotal role in industrial decarbonization efforts worldwide.

The expeditious rate of industrialization and ever-increasing energy demands led to the disproportionate use of carbonaceous fossil fuels, resulting in an upsurge in carbon dioxide (CO_2) concentration. This excess CO_2 in the atmosphere is one of the prime reasons for the currently observed critical climate change effects.1 Hence, decarbonization of the current energy infrastructure has become essential as we try to balance continuous societal growth and environmental protection. In this regard, several nations have come forward and pledged to limit their CO_2 emission in an attempt to control the damage. The atmospheric CO_2 concentration directly influences the global temperature; hence, the CO_2 emission regulation strategy is reckoned as one of our primary moves in this regard (Figure 1). In order to attain a safe level, the CO_2 concentration should be < 350 ppm. As 1 ppm atmospheric CO_2 represents ~7.8 billion tons of CO_2, we need to develop a sustainable and user-friendly pathway to handle such a massive volume of CO_2 gas during operation. Therefore, the demand for an efficient and adaptable technology has become indispensable for reducing and capturing CO_2 directly from the ambient air and the industry-emitted flue gases.

Specific problem or pain point does your technology aim to solve

The International Energy Association (IEA) statistical report provides the fact that our society has already reached the maximum rate of CO_2 emission. Therefore, establishing a net-negative CO_2 emission technology has become a prerequisite for negating the effects of climate change. In the present scenario, the appropriate implementation of CO_2 capture, utilization, and storage (CCUS) technologies seems to be the best way forward as we continue to deploy our current energy infrastructure. The inclusion of the CCUS measures into traditional technologies is typically regarded as the shift to the "blue technologies." Such blue technologies are often considered the way forward to renewable-driven green technologies, which currently fail to match up with the global demand. Considering all the overarching factors, blue technologies emerge as the fastest route and more implementable solutions for industries to achieve net zero in the current scenario. Nevertheless, similar to every other implementable technology, CCUS is also needed to be cost-effective and revenue-generating. However, none of the currently available high-TRL CO_2 capture technologies for CCUS, like absorbent, recti sol, and cryogenic, are sustainable, energy-efficient, cost-effective, and revenue-generating. UrjanovaC Pvt. Ltd., has developed a unique catalyst-driven CO_2 capture process in water to generate market-ready minerals as the final product. Hence, this novel CO_2 capture technology has the potential to respond to all the existing major drawbacks of CCUS technology.

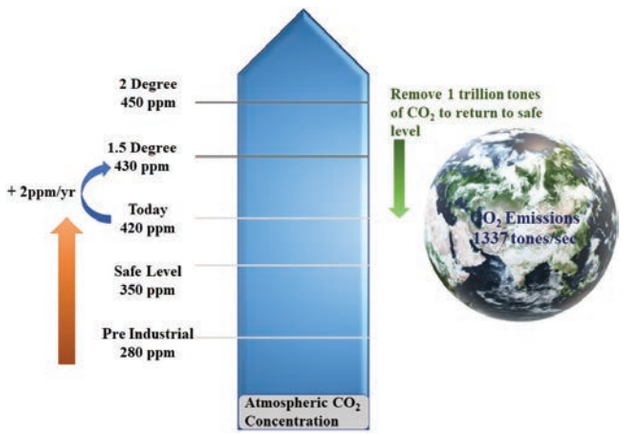


Figure 1. The effect of atmospheric CO2 on global temperature.

USP of solution and how does your technology address the root cause of the problem

The heart of the process developed by lies around the unique application of a robust, inexpensive, and scalable catalyst, which captures CO_2 at a rapid rate in water. Interestingly, this catalyst even operates in industrial wastewater or seawater while it cleanses flue gas directly without any prior treatment under practical conditions. The exclusive technology is currently upgraded for a ~1.0-3.0 ton CO_2 capture unit. The patented catalyst assists in the fast dissolution of captured CO_2 into bicarbonate and carbonate ions, which can be readily mineralized into carbonate minerals by adding abundantly available group-II metals from natural resources or industrial wastes. Therefore, this technology is an ideal case of waste-to-wealth, where the pollutant CO_2 is strategically transformed into valuable minerals to create a circular economy.

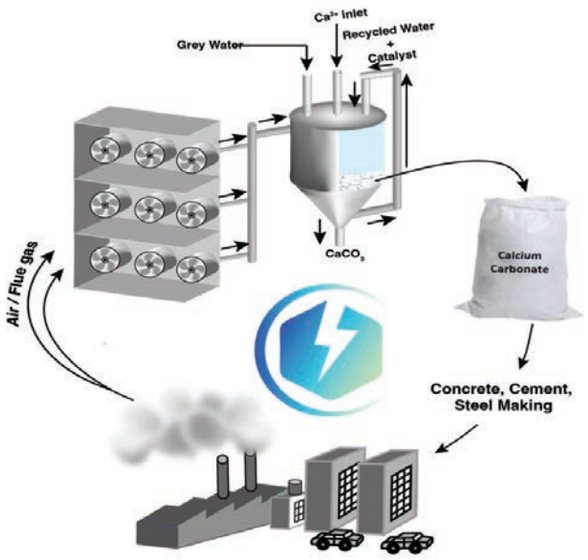


Figure 2: Schematic representation of UrjanovaC technology.

The salient features of the technology are as follows:

- Instead of using hazardous compounds, this technology only uses benign water (even industrial wastewater or seawater can be used) and readily available bases as the raw materials, along with our patented catalyst for CO_2 capture (> 90% efficiency).
- The catalyst is durable, inexpensive, and non-toxic in nature and can be recycled for >1000 cycles for continuous usage over a three-month period.
- The catalyst can capture CO_2 from variable sources: air (~0.04% v/v) to pure stream (100%). Therefore, this technology can be employed for both Direct Air Capture/DAC and flue gas capture.
- This technology can also capture SOx and NOx in the same converter. Hence, a direct flue gas source can be used in this technology without any pre-treatment.
- The technology produces commercially viable precipitated calcium carbonate (PCC) as an end product. Here, the calcium carbonate belongs to the calcite mineral with a purity >99%, while the final product can be customized from bulk pallets to nanosized powder.
- This technology is retro-fittable in any industrial plant with minimum infrastructural modifications.
- The space requirement for this technology is substantially less compared to other existing carbon removal technologies. Typically, UrjanovaC Carbon removal technology takes up around ~20 square-meter area for 1.0 TPD unit.

Technology stack and methodology of implementation

The implementation of UrjanovaC technology is executed in two phases.

- The first phase is the pre-feasibility and FEED study, which will analyse
- Flue gas composition,
- Scale of the capture unit,
- Waste - disposal procedure,
- Techno - economic feasibility analysis and
- Final implementation design.
- After that, the plant deployment starts in the second phase. The two-phase implementation process ensures smooth running and the incorporation of necessary customization in the plant set-up as per the industry requirement.

Value Proposition

The unique value propositions of the technology are as follows:

- Scalability: The catalytic process of this technology ensures the CO_2 removal scalability on a million-ton scale.
- Sustainability: The major raw materials of this technology are non-potable water and a non-hazardous catalyst as it converts CO_2 to benign carbonate minerals.
- Circularity: The technology primarily closes the carbon loop in an industrial setup by utilizing waste CO_2 to produce carbonates.
- Cost Competitive: Although the CAPEX is comparable with all other competitive technologies, the OPEX is ~50% less as it operates at ~ USD 20-25 per ton of CO_2 capture.

Targeted customers and market opportunity

The target market encompasses power, steel, and cement, among other hard-to-abate industries. Utilizing our patented DAC and CCU technology, thus can produce carbonate as an end product. The global carbonate market is valued at USD49.5 billion in 2022 and is projected to be USD72.5 billion by 2030. Thus, carbonate not only serves as a valuable commodity but also removes CO_2 from the atmosphere through mineralization, significantly reducing the carbon footprint of traditional carbonate production from limestone or dolomite.

Additionally, our patented CO_2 electrolyzer technology converts CO_2 into carbon monoxide (CO), a crucial reagent in various industries. CO is a precursor for numerous carbon-based compounds, including formic acid, oxalic acid, methanol, ethanol, and synthetic gas. The global CO market is valued at USD2.52 billion in 2022 and is expected to reach USD5.38 billion by 2032.

Business model & revenue strategy

Our business model features four key revenue streams:

- Pre-feasibility, Feasibility, and Front-End Engineering and Design (FEED) Studies: Collaborate with industries and government bodies to initiate and execute FEED studies using our patented technology. Fees are determined by the scale of the study.
- Prototype Development & Deployment: Team of experienced engineers and experts works closely with clients to develop robust, customized prototypes and assist in their efficient deployment. Pricing is based on the scope and time line of the project.
- Intellectual & Technical Support for Commercial Scale Implementation: Based on the scope of the FEED study, the clients are partner with to provide tailored technical support for the effective commercial-scale implementation of the designs.
- Carbon Credit: A share of the carbon credits earned by our clients are charged, based on current market conditions.

As the world grapples with the pressing challenge of climate change, the implementation of innovative and sustainable technologies is imperative. The biometric CO_2 capture and mineralization technology offers a promising solution by effectively capturing and transforming CO_2 into valuable minerals. This approach not only addresses the critical need for decarbonization but also promotes economic viability through the production of marketable by-products. By targeting hard-to-abate industries and integrating seamlessly into existing infrastructures, this technology stands to play a pivotal role in the global effort to achieve net-zero emissions. The unique blend of scalability, sustainability, and cost-competitiveness ensures its potential for widespread adoption and significant impact on industrial decarbonization. As we move forward, the continued development and deployment of such advanced technologies will be crucial in building a more sustainable and resilient future. ■

Kilian KTP 420X C containment press by Romaco

The containment version of Romaco Kilian's KTP 420X C rotary tablet press fulfills all requirements for processing active pharmaceutical ingredients up to OEB Level 3 with medium toxicological potency. This includes numerous medications, for example for treating hypertension, ventricular ulcers or bronchial asthma. The containment tablet press is configured with a Restricted Access Barrier System (RABS) featuring glove ports to protect the operator as well as a Rapid Transfer Port (RTP) for contamination-free material transfer. Negative pressure in the compaction area and electric door locks as well as dust-tight docking systems and a dust-tight tablet chute moreover ensure GMP compliance. The efficient implementation of high-quality containment processes is additionally supported by the proven hygienic design of the KTP 420X C. The hermetical separation between the compaction and technical areas prevents tablet dust from entering the mechanical compartment. The compaction area itself is designed as a deep-drawn, single-piece run-off containment with polished surfaces and large radii, so that far less effort is necessary for cleaning. Protective clothing is only required for cleaning the press and is not essential during production. The very good OEE (overall equipment effectiveness) and extremely low TCO (total cost of ownership) are key characteristics of the Romaco Kilian KTP 420X C. With a maximum output of 475,200 tablets per hour, the technology is classed as a high-speed press for containment applications. ■

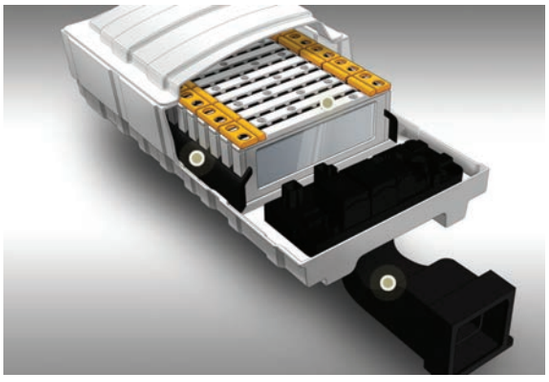
OmniStar from Pfeiffer Vacuum-Universal leak detector

The ASM 340 is a versatile leak detector for hydrogen and helium. The ASM 340 can be used not only for qualitative localization of leaks but also for quantitative integral or local testing. Its powerful vacuum system sets it apart and guarantees extremely fast operational readiness. It also features a rapid response time due to its high helium pumping speed. These characteristics result in short cycle times and a high throughput rate. The ASM 340 is the only leak detector in its class capable of locating leaks at pressures below 100 mbar. Leakage testing of fuel cell stacks, hydrogen tanks and integrated hydrogen circuits are a main focus. ■

Rittal develops megawatt cooling for AI

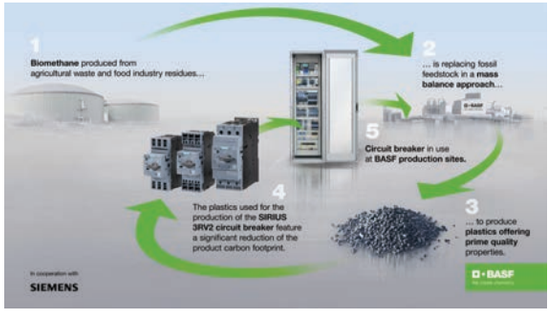
Rittal's modular platform for single-phase direct liquid cooling offers advanced features for data centers. It uses coolant distribution units compatible with water, ensuring easy maintenance. Modular components like coolant conveying units (CCUs) and central controllers are scalable, supporting rapid infrastructure expansion with high availability and component-level leakage monitoring. The system supports cooling outputs over 1 MW, suitable for bayed or single-rack solutions. It includes liquid-to-liquid solutions for heat recovery and variants for data centers without water connections, expelling heat via rear doors or side coolers. Integrated power, cooling, and monitoring within standardized racks cater to hyperscalers and server OEMs, anticipating high performance and scalability needs in global IT infrastructures. ■

Asahi Kasei Unveils New Lithium-Ion Battery Concept



Asahi Kasei Corp. and its U.S. subsidiary Celgard will showcase a new lithium-ion battery concept at the Advanced Automotive Battery Conference Europe in Strasbourg. The concept features high-performance thermoplastics and separators, highlighting lightweight, flame-resistant structural battery parts. Modified polyphenylene ether (mPPE) Xyron resins are used for battery spacers and cell-holders, offering excellent dimensional and hydrolytic stability, and good electrical properties. Additionally, the design includes an exhaust duct made from mPPE particle foam SunForce, which provides high fire protection (UL94 V-0), high formability, and superior thermal insulation properties. ■

Siemens and BASF Introduce Biomass-Balanced Plastics in SIRIUS 3RV2 Circuit Breaker

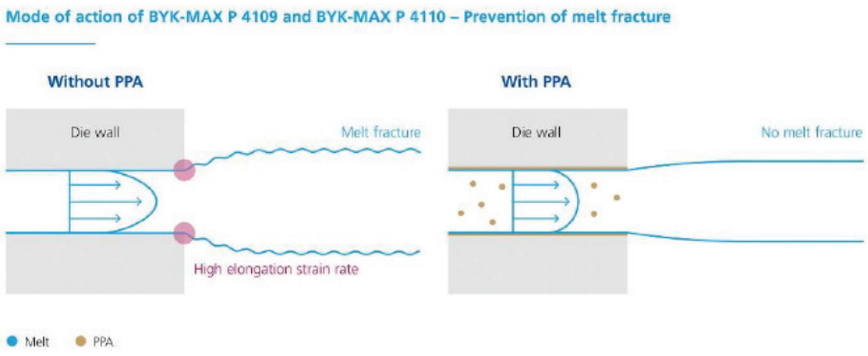


Siemens and BASF have launched the SIRIUS 3RV2 circuit breaker, featuring components made from biomass-balanced plastics. Utilizing Ultramid® BMBcertTM and Ultradur® BMBcertTM from BASF, derived from biomethane sourced from renewable agricultural waste, this innovation reduces carbon dioxide equivalent emissions by about 270 tons annually. Part of Siemens' EcoTech label initiative, the circuit breaker maintains high performance and quality while advancing sustainability in industrial and infrastructure applications. This collaboration underscores both companies' commitment to fostering a circular economy and promoting environmentally friendly practices in product development and deployment. ■

Pfeiffer Vacuum Ensures Safety with Okta ATEX Roots and HiScroll ATEX Scroll Pumps

Pfeiffer Vacuum's Okta ATEX Roots pumps and HiScroll ATEX scroll pumps are designed to meet stringent safety standards in potentially explosive atmospheres. Compliant with the European ATEX Directive (2014/34/EU and/or 1999/92/EC), the Okta ATEX Roots pumps feature a pressure surge resistance of PN 16 and a hermetically sealed magnetic coupling on the drive shaft to prevent zone entrainment risks. They are suitable for applications across industries including chemical, biotechnological, pharmaceutical, and industrial sectors like vacuum furnaces and heat treatment. With options for equipment categories 2G or 3G and suitability for temperature class T3, these pumps offer variable differential pressure and operate efficiently in ambient temperatures from -20 °C to +40 °C. The magnetic coupling design ensures minimal leak rates of 10-6 Pa m3/s, reducing maintenance needs and operating costs by up to 20% compared to pumps with traditional shaft seals. ■

BYK Launches PFAS-Free Additives for Enhanced Polymer Processing



Specialty chemicals manufacturer BYK has introduced two innovative PFAS-free products, BYK-MAX P 4109 and BYK-MAX P 4110, designed for the thermoplastics industry. These additives address challenges such as melt fracture, viscosity reduction, die build-up, and facilitate quicker material changes in the production of films, pipes, profiles, and fibers. Traditionally, fluorine-containing additives have been used to optimize processing conditions in polyolefin production, but regulatory trends are now shifting towards PFAS restrictions. BYK's new additives offer effective alternatives without compromising on performance, ensuring high production speeds and minimizing maintenance by preventing operational issues like die build-up. They also reduce downtime through faster rinsing and facilitate easy handling due to their thermal stability. ■

AMETEK Releases WDG-V HP Combustion Analyzer for High Particulate Applications

AMETEK Process Instruments has launched the WDG-V HP series of close-coupled convective flue gas analyzers, designed to enhance combustion control in high particulate environments. These analyzers provide continuous measurement of excess oxygen (O2) and can optionally measure combustibles (CO+H2) and hydrocarbons, including methane (CH4). Building on the WDG-HPII design, the WDG-V HP employs a unique "chimney effect" convective sampling technology, combining high-particulate sampling benefits with the durability of extractive analyzers. Suitable for flue gas temperatures up to 1537°C (2800°F), it uses zirconium oxide for O2 measurement and catalytic detectors for combustibles and methane. Ideal for applications in cement and lime kilns, glass furnaces, metals and mining, pharmaceutical heaters, power boilers, and pulp and paper recovery boilers, the WDG-V HP ensures reliable combustion control and optimization.. ■

Kobold Introduces MIK Electromagnetic Flow Meter with U-PACE Electronics

Kobold's new MIK electromagnetic flow meter, featuring U-PACE compact electronics, offers precision, flexibility, and durability for a wide range of applications. Designed for neutral and aggressive media, MIK combines flow measurement and dosing in one device, eliminating the need for separate evaluating electronics. It is suitable for industries such as food, chemical, and construction, with measuring ranges from 0.01 to 700 liters per minute.

The MIK uses Faraday's law of induction, where the voltage induced by the flowing liquid is proportional to the flow velocity. The U-PACE system enhances control and precision, providing two configurable outputs and ensuring reliable, maintenance-free operation. The MIK's design allows installation in tight spaces, making it ideal for versatile industrial applications. ■

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R.N.I. No. 11403/1966 Date of Publication: 29th of every month. Postal Registration No: MCS/095/2023-25
Posted at Patrika Channel Sorting Office, Mumbai 400001, on 30th of every month. Total Pages No.: 62

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- Plant Machinery & Industrial Consumables
- Engineering Consultants
- OEMs for Chemicals & Pharmaceutical Processing Equipment
- Metals & Metallurgy
- Bioprocessing Equipment
- Construction Services Providers
- Plant Maintenance Services Providers
- Logistics & Supply Chain Solutions Providers
- Instrumentation & Process Control
- Industry Automation (Process & Factory)
- Systems Integration & ERP Solutions Providers
- Water & Waste Water Treatment Consultants
- Environment Solutions Providers
- Waste Management Consultants
- Financial Institutions
- Fire & Safety Solutions Providers
- Material Handling Solutions
- Certification Bodies
- Welding Solutions
- Quality Health & Environment Solutions
- Analytical & Laboratory
- Packaging Materials, Machinery & Systems
- Business Consultants

Scope for Specialty Chemicals World Expo 2026

- Agrochemicals Intermediates
- Adhesives & Sealants
- Agrochemicals & Crop Protection
- Bulk Drugs & Intermediates
- Enzymes
- Colorants, Dyes & Pigments
- Cosmetics & Personal Care Ingredients
- Hygiene & Cleaning Chemicals
- Laboratory Chemicals
- Surfactants
- Water Treatment Chemicals
- Catalysts
- Electronic Chemicals
- Flavours & Fragrances
- Contract Manufacturers

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- Pharma Ingredients
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- Laboratory & Analytical Solutions
- Process Measurement & Inspection
- Sterilization & Clean Room Solutions
- Biopharma R&D And Manufacturing
- IT Solutions
- Water & Waste Treatment Solutions

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- 750 EXHIBITORS FROM 15+ COUNTRIES
- 25871 VISITORS FROM 53 COUNTRIES
- SCALE@CHEMTECH World Expo 2024: 60+ GLOBAL CLIMATE TECH STARTUPS FROM 20 COUNTRIES; 40 TECHNICAL PRESENTATIONS
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