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AUGUST 2019, ₹100

INTERVIEW

SAJID HUSSAIN
ARCHIS AMBULKAR
PRUTHVIRAJ PARMAR

MUNICIPAL WATER

DISTRIBUTION SYSTEMS

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GLOBAL RISE OF ZERO LIQUID DISCHARGE

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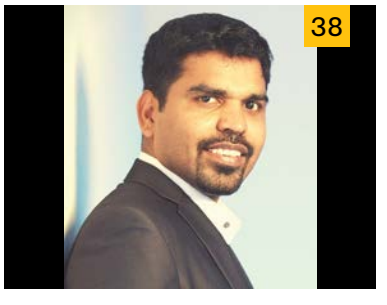
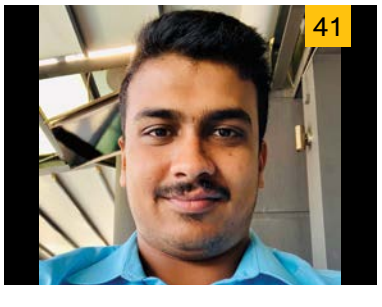
GLOBAL RISE OF ZERO LIQUID DISCHARGE

Smart Water & Waste World talks to Water & Wastewater experts, and covers various aspects of Zero Liquid Discharge (ZLD) to understand the reasons of its global rise as a hot concept in the past few years.





Inside>>

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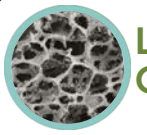

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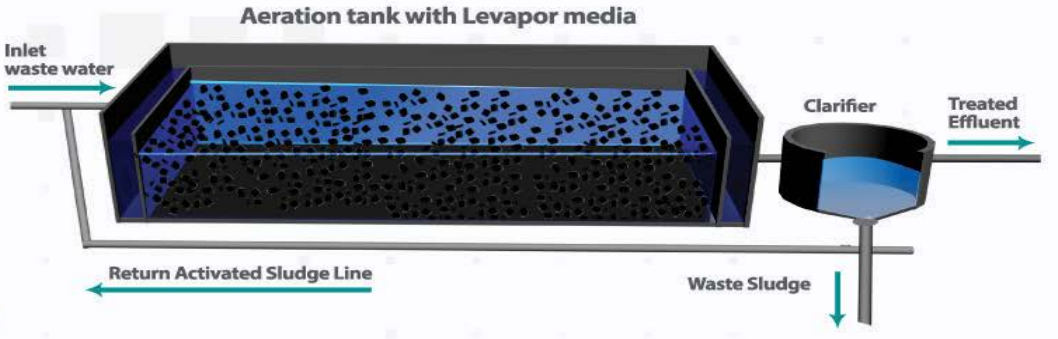

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BIOFILM-TECH GmbH

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+91 7405056112 | amit.christian@levapor.in | www.levapor.com

MAYUR SHARMA | Editor
mayur@smartwww.in
@SmartWWW_IN

> *"We don't need a handful of people doing zero waste perfectly. We need millions of people doing it imperfectly."*
>
> - Anne Marie Bonneau a.k.a. The Zero Waste Chef

The Global Rise of ZLD

Zero Liquid Discharge, or more commonly known as ZLD, is an expanding water treatment philosophy in which wastewater is purified and recycled, leaving little to no effluent when the process is complete.

Frost & Sullivan, in the cover story section of this issue, say that the global ZLD market is estimated to grow from USD 527 million in 2018 to USD 944.5 million in 2024 with a CAGR of 10.2%. While APAC is the fastest-growing market, China and India are the key growth drivers.

Thermal power plants, specifically, ZLD treatment for wastewater generated by the FGD unit is expected to be the key driver in China whereas in India river cleaning projects such as Namami Gange and regulatory enforcement of ZLD for highly pollution industries will be the key driver. The revenues in APAC are set to increase from 25% in 2018 to 29% of the global revenues in 2024.

High Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) are still major restraints for ZLD plants as they usually have higher capital costs compared to other wastewater treatment processes.

ZLD vendors are now increasingly using IoT-enabled wastewater monitoring and handling systems and Artificial Intelligence (AI) technology for improved efficiency and to keep pace with the rate of digitalization in End-User Industries. The rise of Industrial IIoT (Internet of Things) is expected to have strong implications for ZLD systems market.

There are several reasons for ZLD systems and plant manufacturers, suppliers, and consultants to be upbeat. News coming from various segments not only indicates a steady rise in the usage of ZLD but also hints at it being at the top spot for a long time to come.

At SAIL (Steel Authority of India Ltd), ETPs are being set-up at its steel plants to reuse water, while various ZLD projects for these steel plants are under formulation.

Atul Industries, a leading integrated chemical manufacturer, is deploying about Rs 100 crore towards environmental compliance, which would help turn their couple of units into ZLD units.

Sun Pharmaceutical, India's 17 units are currently Zero Liquid Discharge (ZLD), while 5 are currently in the process of obtaining the status.

Delhi state government has asked all the schools affiliated to it to implement the ZLD system in a fixed time period of 90 days, to eliminate the wastage of water.

The National Green Tribunal (NGT) recently ordered the closure of distillery division of Bajaj Hindustan Sugar Ltd in Uttar Pradesh while slapping environmental compensation of Rs. 58.2 lakh for non-compliance of its orders. The tribunal had earlier asked CPCB (Central Pollution Control Board) and state PCB for a report, which disclosed that the distillery unit was not yet fully compliant with pollution control measures, particularly for ZLD.

While the popular notion is otherwise, it is interesting to note that most ZLD systems in a developed country like the USA do not actually recover 100% percent of wastewater. Still, they are very effective. Such programs are referred to as near-ZLD and recover between 70-90% of wastewater for reuse. In our opinion as well, based on various factors, even the near-ZLD could be a good option.

In my last editorial, I had mentioned the upcoming 3rd Edition of our flagship municipal summit - JAL SABHA, 6-8 November, at Le Méridien in Nagpur city. We welcome SWAN (The Smart Water Networks Forum) and Frost & Sullivan as supporting partners of this event. We also extend a warm welcome to confirmed delegates from MCGM, Thane, Vashi, Shirpur, Hyderabad Municipal Corporations and Mission Bhagiratha officials in Telangana.

Our next two magazine issues will be September (Solid Waste & Wastewater: Urban Market Agenda, Recycling, Waste-to-Energy, Landfill Leachate), and October (1st Anniversary issue, Country Focus: Germany & China). I welcome your editorial contributions.

FOUNDER & CEO
Kailash Shirodkar

EDITOR
Mayur Sharma

HEAD - PRINT & ONLINE SALES
Mamta Singh

DESIGN & LAYOUT
Nocturnal Brains

PRODUCTION
Shailesh Iyer

MARKETING
Bhaskar Chivukula

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Grundfos India Promotes the Need for Climate-Resilient Infrastructure

Mayur Sharma
India

GRUNDFOS INDIA WAS the Gold sponsor of the Climate Leadership Conference organized by Confederation Indian Industries (CII) on August 1, 2019 in Delhi, which aimed to discuss possible solutions for the Indian industries to combat climate change.

Moderating the session on 'Building Disaster Resilient Infrastructure for the Nation Against Climate Change Impacts', Ranganath NK, Area Managing Director, INDO Region, Grundfos said, "Climate change is impacting us in many ways. We see the effects of climate change through increased flooding, drought, and drastic weather fluctuations. While we all work towards mitigating the negative impact of climate change, it is important to also focus on adopting intelligent and efficient solutions and technologies that can help us build stronger disaster resilient infrastructure. It is also critical for key stakeholders such as the Government and industries to come together to address these challenges."

Thermax Closes Q1 with 34% Higher Revenue

Mayur Sharma
India

FOR THE FIRST quarter of FY 2019-20, at the consolidated level, Thermax has posted operating revenue of Rs. 1,392 crore, up 34% as compared to Rs. 1,035 crore in the corresponding quarter, last year. Profit after tax for the quarter was 29% higher at Rs. 63 crore (Rs. 49 crore).

As on June 30, 2019, Thermax Group had an order balance of Rs. 5,250 crore (Rs.6,420 crore), down 18%. Order booking for the quarter was 26% lower at Rs. 1,217 (Rs.1,652 crore) on account of slowdown in investment sentiment witnessed in both domestic and international markets.

Pursuant to acquisition of shares in Thermax Babcock & Wilcox Energy Solutions Pvt Ltd (TBWES) and Thermax SPX Technologies Limited (TSPX), their financial results have been consolidated as wholly-owned subsidiaries as compared to 'equity' basis consolidation during Q1, last year. Hence, the results of the group are not comparable.

On a standalone basis, including discontinued operations, Thermax posted operating revenue of Rs. 1,168 crore during the quarter, 38% higher as compared to Rs. 849 crore in the previous year.

LANXESS Remains on Track after a Stable Second Quarter

Guidance for full year 2019 confirmed: EBITDA pre exceptionals of between EUR 1.000 billion and EUR 1.050 billion

SWWW Staff
Germany

SPECIALTY CHEMICALS COMPANY LANXESS is on track despite the weaker economy and geopolitical uncertainties and can look back on a stable second quarter. EBITDA pre exceptionals declined only slightly by 1.4 percent to EUR 286 million, nearly reaching the figure of the strong prior-year quarter of EUR 290 million. The EBITDA margin pre exceptionals remained stable at 15.8 percent after 15.9 percent in the prior-year quarter.

"Our strategic transformation and more stable position are paying off - especially in these economically uncertain times. We delivered good results again in the second quarter and confirmed our guidance for the full year," said Matthias Zachert, Chairman of the Board of Management of LANXESS AG.

Group sales came to EUR 1.810 billion in second quarter of 2019, down 1.0 percent from previous year's figure of EUR 1.829 billion. LANXESS is a specialty chemicals company with sales of EUR 7.2 billion in 2018.

Water Quality Testing Equipment Sales to Surge at CAGR of More Than 5.5% During 2018-2027

The regulatory framework is expected to spur the water quality testing equipment demand within developing economies.

SWWW Staff
Global

WATER QUALITY TESTING equipment sales roughly equated USD 3.4 billion in 2018. According to a new analytical study, sales of water quality testing equipment will surge at a healthy CAGR of more than 5.5% during the projection period, 2018-2027.

Around 70% of the freshwater is used in horticulture, which will continue to establish a strong base for the growth of water quality testing equipment market.

Various industrial applications such as groundwater and surface water investigations of water bodies make it imperative to monitor physical, chemical, and biological parameters of water. This will a significant booster for global water testing equipment market growth through 2027.

The report foresees water quality testing equipment market in the Asia Pacific excluding Japan (APEJ) to hold a substantial share in the global market value in coming years.

These insights are based on a report on "Water Quality Testing Equipment Market" - by Future Market Insights.

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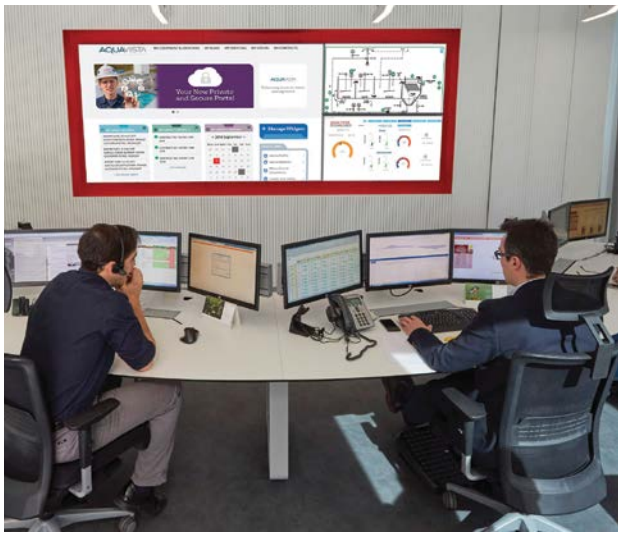
Veolia Wins Contract in South Adams County Water Softening Project 2020



SWWW Staff
USA

VEOLIA WATER TECHNOLOGIES Inc has been awarded a contract to supply pellet softening technology and Aquavista™ digital solution to South Adams County Water and Sanitation District in Colorado.

Working with Carollo Engineers and Moltz Construction, Veolia will provide three 4.6 MGD pellet softening reactors to treat an average influent hardness of 300-350 mg/L. The system will consist of pellet softening flow distribution nozzles, six pellet transfer pumps, a see silo and washer, two PLC-based control panels, valves and actuators, instrumentation and local control panels.

Veolia's cloud-based Aquavista™ performance monitoring system will also be provided with many benefits to SACWSD while taking advantage of the latest instrumentation and IoT functionality. Aquavista™ Portal will provide remote data monitoring for the pellet softening system and provide access from any internet-enabled device.

Veolia was selected based on pellet softening experience, cost savings, and a cloud-based digital offer.

WABAG Announces Q1 FY 2019-20 Results

Mayur Sharma
India

VA TECH WABAG Ltd has announced its financial results for the quarter ended 30th June 2019.

The Q1 FY 19 - 20 highlights include: order book of over Rs. 11,700 crore including framework contracts, order intake of Rs. 2,790 crore, standalone revenue of Rs. 324 crore, standalone EBITDA of Rs. 46 crore, standalone PAT of Rs. 19.9 crore, consolidated revenue of Rs. 457 crore, consolidated EBITDA of Rs. 38 crore, and consolidated PAT of Rs. 2.6 crore.

Commenting on the results, Rajiv Mittal, Managing Director, VA Tech WABAG Ltd said, "We are happy to note that our order intake momentum continues into the new financial year. With the recent order wins in Digha and Kankarbagh - the largest order under Namami Gange till date and the 10-year O&M in Agra and Ghaziabad - awarded under the 'One-City-One-Operator model', we have already crossed 50% of our annual Order Intake guidance within the first quarter of the year."

WABAG Secures Largest Order Under Namami Gange Worth INR 1,187 Crore

Mayur Sharma
India

VA TECH WABAG Limited has secured a order worth INR 1,187 crore from Bihar Urban Infrastructure Development Corporation (BUIDCO) under the National Mission for Clean Ganga (NMCG) scheme to develop Sewage Treatment Plants (STPs) of 150 MLD capacity along with sewerage network of over 450 km in the Digha and Kankarbagh zones of Patna, one of the most populous cities on the banks of river Ganga. This project comprises of a Design, Build and Operate (DBO) scope worth INR 940 crore and hybrid annuity scope worth around INR 247 crore.

Commenting on this major order win, Varadarajan S, Director & Chief Growth Officer, said "With this repeat order in Bihar, WABAG will now be responsible for sewerage infrastructure in 4 out of the 6 zones of Patna, thus testifying the trust reposed by NMCG and BUIDCO on WABAG. All our projects, on completion, will ensure a cleaner and healthier ecosystem for over 50% of the population of Patna."

HCL Foundation Partners with Gautam Buddh Nagar District Administration for Water Conservation Interventions

Mayur Sharma
India

AS A PART of water conservation interventions by the state government of Uttar Pradesh and district administration of Gautam Buddh Nagar and "Harit - The Green Spaces Initiatives by HCL Foundation", HCL Foundation, the CSR arm of HCL Technologies, has signed a Memorandum of Understanding (MoU) with the District Administration, Gautam Buddh Nagar to work towards water conservation interventions and increasing the green cover in Gautam Buddh Nagar district, under HCL's urban development program 'HCL UDAY'.

Effective for 5 years, the MoU was signed between Rajeev Rai, Sub-Divisional Magistrate - Tehsil Dadri, Gautam Buddh Nagar on behalf of district administration; and Nidhi Pundhir, Director - HCL Foundation.

In accordance with the MoU, HCL Foundation and District Administration, Gautam Buddh Nagar will work together to co-develop digital database platform for monitoring, reporting, and verification for existing water bodies in the district.

Nidhi Pundhir is the Global Head of CSR for HCL. She leads the HCL Foundation, as Director CSR which is the CSR arm of HCL Technologies.

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Contact

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9845737908/9136950715

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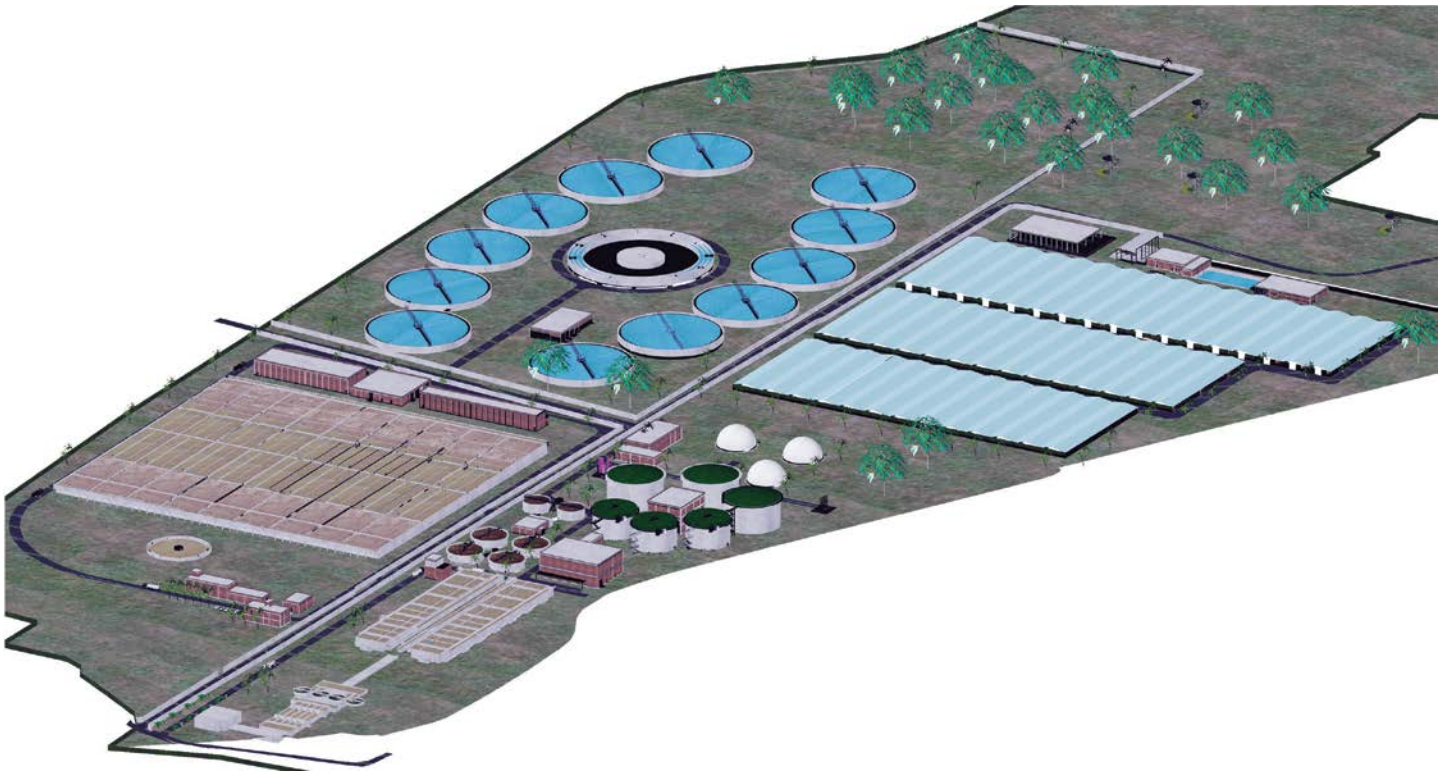
SUEZ Wins a Contract Worth €145 Million to Build & Operate India's Largest Wastewater Treatment Plant in New Delhi

Delhi Jal Board, the authority in charge of water management in New Delhi has awarded SUEZ the contract to build and operate a wastewater treatment plant with a capacity of 5,64,000 m^3/day at Okhla, South of New Delhi, for a value of €145 million.



3D Scheme of Future Wastewater Treatment Plant at Okhla, South of New Delhi, India

The contract provides for a three-and-a-half-year design and construction phase of the plant, followed by an eleven-year operation and maintenance phase. The new plant will replace the old Okhla wastewater treatment plant and will be the largest of its kind in India.

This contract is part of the Yamuna Action Plan III (YAP-III) to restore water quality for the heavily polluted Yamuna River, the main water resource for the capital. The project is funded 81% by Central Government and 19% by Delhi Government.

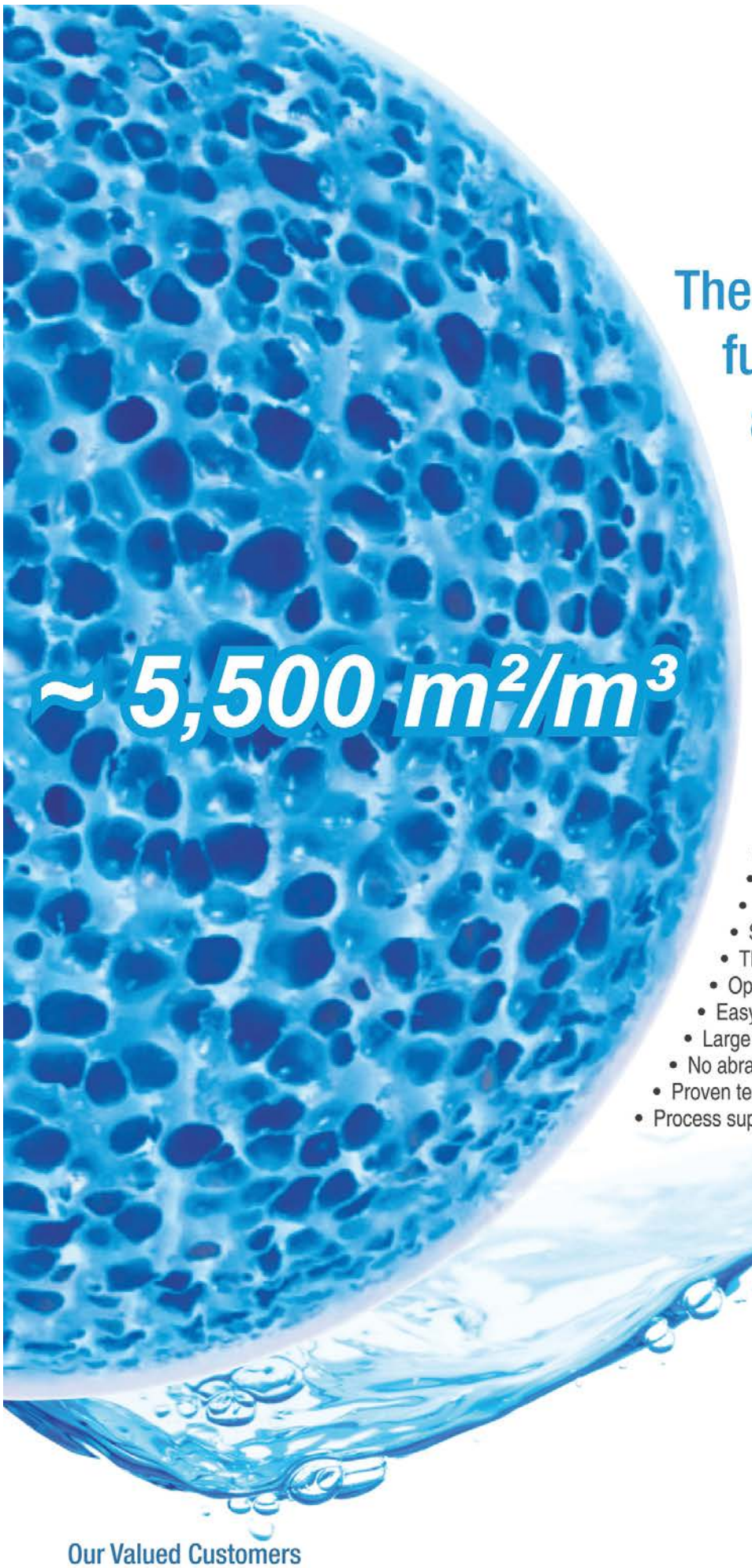
Ana Giros, Senior Executive VP Group, in Charge of International and Industrial Key Accounts, SUEZ

SUEZ will equip the plant with state-of-the-art wastewater treatment technologies to restore optimum water quality to the Yamuna river, in compliance with the latest national standards, requiring a total Nitrogen content of less than 10 mg/l.

The processes deployed by the Group (Digelis Duo2™, Drainis Turbo™) will also significantly reduce the volume of the sewage sludge produced and facilitate their recovery into fertilizer for local agriculture and energy. The production of electricity from sludge recovery will thus cover 50% of the plant's needs.

"For more than 30 years, SUEZ has been supporting large municipalities such as New Delhi, Bangalore, and Calcutta, in the development of innovative solutions to preserve water resources, a growing challenge in a country facing rapid population growth and urbanization. We are proud of the renewed trust of the Delhi Jal Board, enabling us to build and operate this plant, that will be the largest wastewater treatment plant in India. This project allows us to combine technical expertise and customer orientation. It is a concrete example of our shared commitment, with the Delhi Jal Board, to provide quality drinking water and wastewater services to the inhabitants, and to preserve the environment." said Ana Giros, Senior Executive VP of SUEZ Group in charge of the International Division.

SUEZ group *has been present in India for more than 30 years. SUEZ has designed and built more than 250 water and wastewater treatment plants and currently operates 28 of them. SUEZ also plays the role of a water services provider for major municipalities such as Bengaluru, New Delhi, Coimbatore, and Davanagere. Its activities contribute towards the distribution of 5.5 billion liters of drinking water to over 44 million people every day. The wastewater treatment services of the plants built and managed by the company serve some 7.5 million inhabitants. SUEZ employs over 1,200 professionals in the country. SUEZ has over 100 water treatment projects completed for the energy sector, and also leads in the Oil & Gas sector (15 out of the 21 Indian refineries benefit from SUEZ services), as well as the metals, agri-food and textiles sectors. SUEZ employs over 1200 professionals in the country.*



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Nal Se Jal: Playing a Key Role in Developing Water Infrastructure in India

Nal Se Jal - Gagreen Water Supply Project, Rajasthan

SPML INFRA LIMITED, a leading water management company from India plans to play a key role in the development of sustainable water infrastructure to realize the vision of "Nal Se Jal". This ambitious scheme announced by the Finance Minister during her maiden budget presentation aims to provide piped water connection to every household in India by 2024. Given the massive number of connecting about 140 million remaining rural and urban households in five years' time will be a challenging task.

The water resources in India are under tremendous pressure as availability of safe drinking water is not sufficient to cater to the population demand. The rate of groundwater withdrawal is extremely high as compared to available supplies. The effect of expanding cities will see the demand for freshwater supply rising exponentially and with limited resources; India may become a water-starved nation. Over-exploitation of groundwater, failure to recharge aquifers, reduction in catchment capacities due to uncontrolled urbanization and no reuse facility for treated wastewater are all causes for the precarious tilt in the water balance. If the present rate of groundwater depletion persists, India will have only 22% of the present daily per capita water available by 2050, possibly forcing the country to import water. The other prominent challenge being faced by the water sector is the ageing infrastructure of the distribution system. Water utilities in India are faced with the crucial need to address these challenges and revamping of infrastructure on priority for the economic, social, and environmental implications.

The government has placed a well-thought plan of providing drinking water facility to every household of the country that will help to cater to the urgent need to develop adequate water infrastructure. The "Nal Se Jal" scheme will lead to a huge investment in water infrastructure development in the country that will help in addressing the issues of drinking water supply.

SPML Infra Limited started managing water at the time when nobody was talking about it as it was not a business proposition. With sheer commitment and dedication, the company continued to develop water infrastructure in different states. In a rich legacy of about four decades, SPML Infra has completed over 600 projects of infrastructure development out of which more than 500 projects were exclusively in the water supply segment. Presently, the company is providing drinking water facilities to over 50 million people of the country through its various executed projects. With over 25 water supply projects under various stages of execution, SPML Infra Limited features among the World's Top 50 Private Water Companies as per Global Water Intelligence report. From a small water supply project it first executed in Mizoram, SPML Infra Limited is currently engaged in Phase III of the Saurashtra-Narmada Avtaran Irrigation Project (SAUNI Yojana), a very large and ambitious water supply project in Gujarat which envisages providing drinking water facilities to 39 million people across 132 towns and 11,456 villages along with water for irrigation to 1.8 million hectare land, easing the water scarcity concerns in the region. The 24x7 urban water supply projects in Delhi, Pune and 6 cities in Karnataka are helping about 5 million people with clean drinking water facilities.

Non-Revenue Water (NRW) is a universal problem faced across the globe as these losses are real and detrimental to the financial capability of water utilities. In the quest for saving precious water; SPML Infra helped in significantly reducing non-revenue water in Bengaluru by using innovative technology for leak detection in hidden pipes. The experience has been rewarding as the company ensured the NRW reduction from 61% to 27% thus saving of over 40 million liters of drinking water per day. In many Indian cities, the average NRW is as high as 50% of the total water production which reduces the revenue and efficiency of water supply services. In an increasingly complex water situation, the water utilities in India needs to focus on ways of more efficient water management for maintaining water supply systems. Utilities which carefully and creatively use their water assets for strategic urban advantage will ultimately be more sustainable and competitive.

"With ever reducing water sources and increasing demand complexities, it is essential that we rework on our priorities towards drinking water supply and resource development. The newly formed Jal Shakti Ministry is on the mission to provide clean drinking water to every household in the country and has been allocated good budget to ensure piped water supply under the Jal Jeevan Mission."

"I am very happy that SPML Infra Limited's expertise in water management and our strong credentials in infrastructure development will give us a clear edge over others to execute and deliver large value water supply projects. The number of water projects executed by us confirms the added-value solutions and expertise that we provide to our water utility and municipal clients. The company's competence, sectorial knowledge, and pan India experience increases its ability to deliver several water infrastructure projects simultaneously. Our expertise in laying over 10,000 kilometers of water pipeline, construction and erection of high value pumping stations along with a large number of urban and rural water supply projects will help us in executing water supply projects with precision and speed required to complete the mammoth task of connecting all households with piped water supply in the next five years."

"With the experience and execution capabilities, we were able to better address the key challenges in the water space. Considering the niche position we have created for ourselves; we intend to use it to expand our footprints in water projects. We are looking forward to continue our association with government ministries, municipalities and other implementing agencies to receive and execute new projects in water supply segment with integrated strengths of engineering, process technology, and project management."

- Subhash Sethi, Chairman, SPML Infra Limited

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BlueTech Names 15 Water Technologies to Watch

LG Sonic's Solar-Powered MPC-Buoy for Real-Time Monitoring was One of the 15 Technologies Shown at BlueTech Forum 2019.

THE INNOVATION SHOWCASE at BlueTech Forum 2019 featured more companies than ever before. The 15 water technology companies which took part were selected from across the world and boasted highly innovative technologies addressing some of the water industry's biggest challenges.

Potential applications included micropollutant detection, decentralized wastewater treatment, resource recovery, sludge management, and zero liquid discharge. Technologies include a cloud-based Artificial Intelligence (AI) system for water main condition assessment, energy-efficient UV-LED drinking water disinfection systems and a bio-based adsorbent material that can be customized to capture micropollutants from wastewater.

BlueTech Forum took place on 5-6 June in Kew Gardens, London, UK. The Innovation Showcase gives delegates the chance to hear directly from a rich mix of start-ups and global corporations bringing frontline research and development to effective implementation and commercial success.

Paul O'Callaghan, Chief Executive of BlueTech Research said, "The Innovation Showcase is a fantastic opportunity for delegates to hear more about the technologies BlueTech Research's analysts are tracking throughout the world. The theme of BlueTech Forum 2019 is 'innovating towards resilient water systems' and the technologies selected by our expert analysts are those we believe have the greatest potential to drive resource efficiency and address water scarcity. Companies have come from Australia, North America, India and across Europe. The event introduces them to the partners who can make use of their expertise and help them scale and grow."

Fifteen to Watch

The 15 technologies featuring in the Innovation Showcase at BlueTech Forum 2019 included:

1. **Acuva, Canada:** Advanced UV-LED drinking water disinfection systems.
2. **Aqualia, Spain:** Large-scale integrated microalgae-based wastewater bio-refineries for the production of agricultural fertilizers, bio-stimulants, bio-pesticides and feed additives.
3. **Aquatech, India:** Advanced vacuum membrane distillation process that combines thermal and membrane treatment for direct treatment of reject reverse osmosis and brine streams to recover high-quality distillate and meet zero and minimal liquid discharge requirements.
4. **CustoMem, UK:** CustoMem Granular Media (CGM) is a bio-based adsorbent material that can be customized to capture micropollutants from wastewater, including pesticides and pharmaceuticals.
5. **DeSaH, Netherlands:** Decentralised wastewater treatment system which can generate biogas through anaerobic digestion, produce fertilizer through struvite precipitation and recover greywater for reuse.
6. **Electro Scan, USA:** Machine-intelligent probes that automatically locate and quantify defects in water quality at a rate of liters per second.
7. **Eliquo Water, Germany:** EloVac-P is a system for removing phosphorus from wastewater. Digested sludge is degassed prior to dewatering and the phosphorus is precipitated in the vacuum reactor tank and retained as micro-crystals in the sludge after dewatering.
8. **Fracta, USA:** A cloud-based technology employing AI to assess, calculate and visualize the condition of water distribution mains.
9. **Iota Services, Australia:** A company that harnesses, commercializes and shares innovations proven by Australia's South East Water so other utilities around the world can benefit from reduced operating costs and improve their customers' experiences.
10. **LG Sonic, Netherlands:** MPC-Buoy is a floating, solar-powered system that combines real-time water quality monitoring, satellite data and ultrasound technology to control harmful algal blooms in large water surfaces.
11. **Nijhuis Industries, Netherlands:** Nijhuis Electro Osmosis (NEO) is a cost-saving and energy-efficient sludge management solution that can dewater sludge up to 40-50% dry solids.
12. **PowerTech Water, USA:** The capacitive coagulation (CapCo) process removes heavy metals from water streams without the use of chemicals, membranes, or adsorbents. Activated carbon electrodes and small applied potentials operate in an active filtration process to permanently remove metals with >99% selectivity and no sludge production.
13. **Typhon Treatment Systems, UK:** World's first validated LED-UV System, designed to treat continuous flow rates in the range suitable for industrial and municipal applications.
14. **Vienna Water Monitoring Solutions, Austria:** ColiMinder is a fully-automated rapid microbiological measurement technology measuring microbiological contamination in 15 minutes.
15. **WaterMax, Switzerland:** Proprietary aeration technology for hyper-oxygenation of wastewater in treatment applications. WaterMax technologies generate nano-bubbles that improve efficiency, effectively reducing energy and operational costs.

BlueTech Research Chief Executive Paul O'Callaghan Says that the Event Introducing the Technology Companies to Partners who can Make Use of Their Expertise and Innovations.

Global Electric Vehicle Battery Reuse and Recycling Market

By Frost & Sullivan

THE GLOBAL ELECTRIC vehicle battery reuse and recycling market stands at USD 61.5 million as of 2018 and is expected to reach USD 7809.1 million by 2025, recording a CAGR of 99.8%. The reuse segment is currently at a nascent stage in terms of revenue; however, over the next 5 years recycling of EV batteries is going to gain traction. With escalating metal prices especially cobalt and impending new legislative drivers such as the dedicated EU Directive for electric vehicle batteries recycling, the recycling market is expected to kick start with exponential growth from 2021 onwards.

The electric vehicle market reached over 1.6 million sales in 2018 with more than 165 models available for sale. Close to 20 million electric vehicles are expected to be sold across the world by 2025, recording a CAGR of 41.7%. China is leading the market with 51% market share, followed by Europe with 26%, North America with 19% and Japan with 4%. Increasing oil prices, demand urban vehicles, megacities and focus on sustainable transportation has kick-started a substantial trend towards automotive electrification such as hybrids and electric vehicles. Over 2.9 million electric vehicles are likely to be sold globally in 2019 in which 59% will be Battery Electric Vehicles (BEVs) and 41% will be plug-in hybrids, recording a Y-o-Y market growth of 78.1%.

The global electric vehicle battery reuse (2nd life) segment generated revenue of USD 51.24 million in 2018 and is expected to reach USD 1284.91 million by 2025, recording a CAGR of 58.5%. Currently, automobile companies are reusing and reassembling end-of-life electric vehicle battery packs and offering them as lower-cost replacement batteries for older electric cars. Residential and commercial customers also use them in combination with on-site solar power for backup supply. For example, the batteries from lower-range electric vehicles, such as the Chevy Volt and Cadillac ELR, could provide half a day worth of household electricity usage, while batteries from higher-range electric vehicles, such as the Mercedes SLS and the Tesla Model S, could provide a few days of household electricity usage. Several major power utilities are working with companies - including General Motors, Ford, Toyota, and Nissan - to explore the use of the batteries for stationary storage of the power produced in off-peak periods by wind turbines and solar generation stations. Lithium-ion packs also are being tested as backup power storage systems for retail centers, restaurants, and hospitals, as well as for residential solar systems. EVgo has announced its plan of utilizing second-life batteries to its grid-tied public fast-charging systems. The packs have been wired up through a 30kW inverter that allows the packs to add significant value to a charging session by avoiding demand charges that might otherwise be incurred.

The global electric vehicle battery recycling market, on the other hand, generated 2018 revenue of USD 10.26 million and is expected to reach USD 6524.20 million by 2025, recording a CAGR of 151.5%. Out of the revenue generated hydrometallurgical process constituted 59%, followed by the pyrometallurgical process at 39% and other recycling technologies at 2%. In the pyrometallurgical processes, various components of battery cells are liquefied using high temperatures that enable the recovery of the transition metals such as nickel, cobalt, and copper, while lithium and aluminium remain in the slag. Hydrometallurgy processes use in-solution chemistry to isolate component chemical compounds from battery waste. It is considered appropriate for the recovery of 18 metals from Lithium-Ion Batteries (LIBs), due to the good purity, low energy requirements and minimal air emissions. Mechanical methods are generally recognized to be an effective pre-treatment to deal with spent LIBs; these methods include sieving, crushing, magnetic separation, and so on. Belgian based Umicore, a leading supplier of key materials for rechargeable batteries, uses a combination of pyro and hydrometallurgical process to recycle all types and sizes of batteries. The company has the facility to recycle about 35,000 electric vehicle batteries per year. The process is mainly designed to recover nickel, cobalt, and copper as an alloy, which is further processed by hydrometallurgical methods.

The second use of electric vehicle batteries is often seen as an opportunity to delay disposal and recycling, which currently presents burden for OEMs, as well as an opportunity to squeeze value out of existing resources. Sumitomo has established the world's first large-scale power storage system in Osaka utilizing exclusively EOL Nissan Leaf batteries repurposed by 4R Energy.

Collaborative partnerships between public and private entities will be a paramount strategy for effective advanced vehicle battery recycling. Vertical integration along the value chain presents an opportunity for system owners to increase profit margins and decrease their carbon footprint, in addition to providing benefits to other stakeholders. To facilitate recycling, new energy car battery producers are focusing to adopt standardized and easy-to-dismantle designs and share information about battery controlling systems' interfaces and communication protocols. The BMW Group, Northvolt, and Umicore have formed a joint technology consortium to work closely together on the continued development of a complete and sustainable value chain for battery cells for electrified vehicles in Europe.

Innovative business models like the Tesla-Umicore partnership create arrangements that are as good for the company as they are for the community, and show how a recycling system can be both profitable and environmentally sound. Supportive rules and regulations that focus on recycling Li-ion batteries will alleviate material scarcity, lower costs of the materials, and avoid production impacts, including the reduction of energy use, emissions, and mining impacts. Solid investment in the collection and recycling infrastructure and technology for the new generation vehicle batteries, along with effective regulation, will promote higher collection and recycling rates for Li-Ion batteries.

Battery lifecycle management is a huge emerging opportunity that could solve the issue of how to stop electric vehicle batteries ending up as expensive and toxic landfill waste. Enabling new business models, such as "storage-on-demand" and "storage-as-a-service," would allow emerging energy companies to generate new revenue streams without creating a new asset.

About the Author

Anagha Lakshmi *Jayaprkash is a Research Analyst at Frost and Sullivan.*

@FrostSullivanEE

When it Comes to Irrigation, Less is More

The 'Rally for Rivers Draft Policy Recommendations' document highlights the mandatory practice of micro-irrigation in the agricultural sector and explains why it's a winner.

By Rally for Rivers

INDIA IS ONE of the highest extractors of groundwater in the world - most of which is used for irrigation. This isn't good news for a country with only 4% of the world's freshwater resources but 17.5% of the human population. But there is good news - there's a much more efficient way to irrigate: micro-irrigation. When it comes to irrigation, less is more.

India has the second-highest irrigated area in the world but most of it is still under conventional flood irrigation, a 1000-year old practice that involves flooding agricultural land through open canals and field channels. It's essential for the land to be leveled and shaped for all parts to receive water equally. Otherwise, plants at the lower levels will rot from excessive water and plants at higher levels will wither due to lack of water. It's a highly inefficient practice - most of the water is lost in evaporation, runoff or deep percolation resulting in overall irrigation efficiency as low as 40-60%.

Micro-Irrigation: Killing Many Birds with One Stone

Drip irrigation is an advanced method of micro-irrigation with an overall water application efficiency of 90-95%. It needs no land leveling, regulates the water needs of plants by delivering water directly at the root zone and only irrigates cropped land. As water is conveyed through a network of pipes and delivered precisely, almost nothing is lost in transit. It can be automated (which is not possible with conventional flood irrigation) saving time, effort and resources for the farmer.

More good news: Micro-irrigation avoids soil erosion and soil type plays a less important role in the frequency of irrigation. Other advantages include uniform water distribution, low labor cost, and customized supply depending on crop need, minimum wastage of fertilizers and reduced risk of disease. On a conservative estimate, micro-irrigation improves water use efficiency by 50%, i.e., it needs only half the water required in flood irrigation. Several countries in the world have successfully adopted micro-irrigation. China, the US, and Israel can produce the same amount of crops as India, using significantly less water.

An Israeli micro and drip irrigation company, NETAFIM, has been working with the Tamil Nadu Agricultural University (TNAU), Coimbatore, to demonstrate how rice - a traditionally water-intensive crop - can be cultivated through drip irrigation. Rice farmers who switched from flood irrigation to drip irrigation saved 45% water and 25% fertilizers. NETAFIM has also worked successfully with community drip irrigation projects in Maharashtra and Karnataka.

In India, the National Committee on Plasticulture Application in Horticulture has observed that micro-irrigation increases yield across various crops. Sugarcane, usually cultivated with flood irrigation, saw a 99% increase in yield with micro-irrigation.

So, Why Isn't It More Popular Than It Is?

If micro-irrigation checks all the right boxes, why isn't it more popular with our farmers? The answer is never as simple as the question. The cost is prohibitive for small farmers. Awareness about drip irrigation and its advantages is not widespread. The system needs technical expertise which most farmers don't have access to. Erratic power supply and unscheduled outages are extremely disruptive to irrigation systems.

There is a way out, though. The Rally for Rivers (RfR) Draft Policy Recommendations document suggests providing technical and financial support to farmers to make the adoption of micro-irrigation mandatory. It recommends introducing low interest/zero percent bank loans or product subsidies for micro-irrigation to make it easier on the farmers' pockets. It also recommends that the Government's 'Per Drop More Crop' micro-irrigation scheme be put to use in the target area of river revitalization.

Outsourcing large-scale micro-irrigation to experienced organizations will optimize cost and efficiency. This should be done in a way that it preserves the farmer's right over his land and the right to make his own crop choices. Farmers lose much time waiting for water for flood irrigation. With micro-irrigation, they can focus on farm-operations and engage in other income-generating activities. This will reduce agrarian distress.

Different micro-irrigation models are available. Choosing the right model takes into consideration land ownership and holdings, types of plantations, available resources like electricity in close vicinity and farmer preferences.

Co-operative lift irrigation schemes and government lift irrigation projects may be the most effective in tackling the dual challenges of water scarcity and high cost. In co-operative schemes, water lifting infrastructure like pump houses, distribution networks, and others are common and the infield water application system is owned by farmers. It should be mandatory to adopt drip systems in new farmers' cooperatives and existing schemes should convert to micro-irrigation. This can result in a water-saving of up to 50%.

Gotkhindi village in Maharashtra first experimented with large-scale community drip irrigation. Though the scheme was established in the 1980s, it had poor results due to several challenges. A fully automated Gotkhindi Drip Irrigation Project was installed and commissioned in 2011 and has been running successfully since then. The project beneficiaries are enjoying improved crop quality and increased crop yields with reduced cultivation cost.

Government lift irrigation projects are an alternative to co-operative schemes. It avoids permanent land acquisition which is difficult and costly. It ensures equitable water distribution; doubles irrigation area with the same limited available water decreases the gap between Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU). Karnataka has executed the Ramthal Drip Irrigation Project with NETAFIM, a mega-community drip irrigation project for an area of 24,000 hectares and 100% financed by the government of Karnataka; 14,000 farmers benefit from the scheme which had a very short implementation period of 18 months.

It is time for India to design appropriate policies to promote micro-irrigation and ease the burden both on our water resources and on our farmers.

About the Author

Praveena Sridhar *is a Lead Policy Expert at Rally for Rivers, Isha Foundation, and has several years of rich and diverse experience in water and related sectors.*

@RallyForRivers

A Blue-Green Future for Cities

Cities are turning to Blue-Green Infrastructure solutions that utilize ecosystem services in the management of water resources while providing multiple co-benefits.

By Robert C. Brears

BLUE-GREEN INFRASTRUCTURE (BGI) is a strategically planned network of natural and semi-natural areas that are designed and managed to deliver a wide range of environmental, economic, and social benefits. These benefits include:

- **Improved Water Quality:** When rain falls on a city's surfaces (streets, sidewalks, and rooftops), it collects oil, litter, and other pollutants as it runs off the city surfaces into waterways. BGI enables cities to capture and clean this stormwater, ensuring waterways are healthier.
- **Reduced Potential for Flooding:** BGI slows down and holds stormwater allowing it to soak into the ground. This helps reduce the volume of water entering the sewer system and prevents flooding.
- **Reduced Sewer Infrastructure Cost:** BGI reduces the volume of water entering the sewer system by returning water to the natural water cycle. This increases the lifespan of the sewers and reduces infrastructure maintenance costs.
- **Increased Green Space for Communities and Wildlife:** BGI provides multiple mental and physical health benefits to communities as well as a sanctuary for urban wildlife and pollinators.

In addition to managing water - too much and too little - BGI provides a whole range of benefits to cities and their residents. For instance:

- **Water Regulation:** BGI solutions such as swales, rain gardens, and green roofs increase the infiltration and slow down rainfall entering the drainage system, reducing the likelihood of localized flooding during heavy storm events. Meanwhile, collected water in rainwater harvesting systems can be used for outdoor irrigation and some non-potable indoor uses, reducing municipal water use.
- **Urban Heat Island Effect:** Because BGI involves using plants and trees, they naturally cool down surrounding air temperatures by shading building surfaces, deflecting radiation from the sun, and releasing moisture into the atmosphere. This helps reduce the urban heat island effect as well as lower energy bills in adjacent buildings (less demand for aircon).
- **Improving Air Quality:** BGI can improve air quality with vegetation reducing the amount of emissions people are exposed to. It does this by changing the speed and distance pollutants travel before they reach people: the further the distance the more the pollution is diluted with cleaner air. The human health impacts of improved air quality are lower respiratory ailments, including chest pain, coughing, and asthma, and fewer premature deaths.
- **Enhancing Community Well-Being:** BGI can provide recreational and physical activity opportunities, with physical activity shown to reduce stress and the risk of obesity, cardiovascular disease as well as improvements in mental health. Attractive BGI also improves community identity and sense of place, as well as offering a place for gathering and social interaction.
- **Economic Benefits:** BGI can defer or even replace costly grey infrastructure projects (e.g. major sewage expansions and deep tunnels), which are costly to construct and take years to complete, making them vulnerable to rising costs of materials, labor, and financing. BGI can also create green jobs through construction, maintenance or management of various BGI initiatives as well as through increased tourism related events taking place in environments with BGI.

Milwaukee's Blue-Green Future

One example of a city moving towards a blue-green future is Milwaukee, which has released its 'Green Infrastructure Plan' to help the city adapt to climate change while creating a healthier and resilient city. Already, the city is on its way to this future with a variety of programs in place.

The aim of Milwaukee's Green Infrastructure Plan is that by 2030, Milwaukee will add around 36 million gallons of stormwater storage by implementing green infrastructure, the equivalent of adding 143 greened acres throughout the city.

Green infrastructure, in addition to managing excess stormwater, provides multiple environmental, social, and economic co-benefits including providing urban habitat, promoting biodiversity, protecting water bodies from pollution, adding green space amenities, beautifying neighbourhoods, and reducing the water entering sewers for treatment.

Already, the city is on its way to achieving its goal through a variety of programs currently in place.

Commercial customers can offset their stormwater management charge by installing green infrastructure on their property with reductions capped at 60% of the stormwater charge. The charge is based on an 'Equivalent Residential Unit', in which all residential customers are charged a uniform fee per residential unit (for 1-4 unit properties the current quarterly fee is USD 20.79 per 1 ERU) and commercial customers pay a fee based on the total area of impervious surface on the property: One ERU is equivalent to 1,610 square feet of impervious surface and so the annual fee is USD 0.051/square foot impervious surface [(USD 20.79 x 4 quarters)/1610]. The city caps the reduction at 60% to cover the remaining operating and maintenance costs associated with the city's collection and conveyance systems.

With parking lots representing a significant percentage of total impervious surface area in the city, the City will offer grants to implement green infrastructure in commercial property. Applicable properties must be non-residential and currently paved with non-porous asphalt or cement. The program can provide funds for projects larger than USD 25,000 with funds provided as reimbursement following successful completion of the project within 2 years of project approval and a signed 10-year conservation easement with Milwaukee Metropolitan Sewerage District (MMSD).

With green infrastructure able to directly improve the lives of children, especially schoolyards that include large areas of impervious surfaces, the City has entered into a partnership with Milwaukee Public Schools (MPS) to implement green infrastructure in school and schoolyard capital improvement projects. With the city pledging USD 600,000 annually to support 4-5 green schoolyard projects per year, participating schools will remove excess asphalt and pavement and replace it with functional green space.

MMSD invites both public and private sector organizations who plan to install green infrastructure strategies on their properties to submit applications for partnership funding for the 2019 Green Infrastructure Partnership Program. Applications can be made for strategies that include creating new rain gardens, bioswales, green roofs, and other techniques to capture and harness stormwater and melting snow. Applications are competitively scored based on an established set of criteria focused on the applicant's ability and commitment to implement, maintain, and promote the project.

***Robert Brears** is the author of Urban Water Security, Founder of Mitidaption, and Our Future Water.*

@Mitidaption

GKD: The Success Story Continues

The company's sales revenue have increased by almost ten percent.

The CEOs of GKD, Ingo (left) and Dr. Stephan Kufferath (right), can Reflect on an Encouraging Business Performance in 2018 © GKD/ Emil Zander

THE TECHNICAL WEAVERS for industry and architecture GKD - Gebr. Kufferath AG (GKD) continued their success story in the 2018 financial year: With sales revenue that rose to 95.3 million euros, the GKD Group exceeded the previous year's figure by 9.6 percent. All business divisions and subsidiaries contributed to this positive result, allowing the third-generation owner-managed family company to further expand its position as the global market leader in defined niche markets. The growth course was also evident in the 14 percent hike in employees: As at the balance sheet date of December 31, 2018, GKD employed 871 people throughout the group, 457 (+3.2 percent) of them at the headquarters in Düren, Germany. In the reporting year, GKD invested a total of 4.8 million euros in the future. Alongside further modernization, automation, and capacity expansion of machines and plant, a major focus was the expansion of the Düren company headquarters with an extra 700 square meters of office space.

In four business divisions - Industrial Mesh, Process Belts, Metal Fabrics, and Transparent Media Façades - GKD is the global market leader for technical weave made of metal and plastic as well as spiral mesh. A global presence is ensured by six company-owned factories as well as branches and agencies worldwide. "The basis of our success is the breadth of our technology portfolio combined with our rigorous pursuit of technological leadership in the relevant markets," says GKD Director Dr. Stephan Kufferath. In conjunction with the intensive internationalization the company has practiced for years, this strategy gave rise to continued success in the 2018 financial year. With an increase of 38.7 percent, the U.S. market was the main contributor to the growth in sales revenue. This upturn was due primarily to a major expansion of group's own production activities and a new production site in the USA. Despite a good performance by GKD India, Asia, and Australia were unable to match the previous year's success (-38.2 percent). In 2017, the major architectural project for the Tencent headquarters in China was the key factor in a record result for Asia. In Europe and South Africa, the sales climbed by 7.5 percent.

Solution Expertise in High Demand

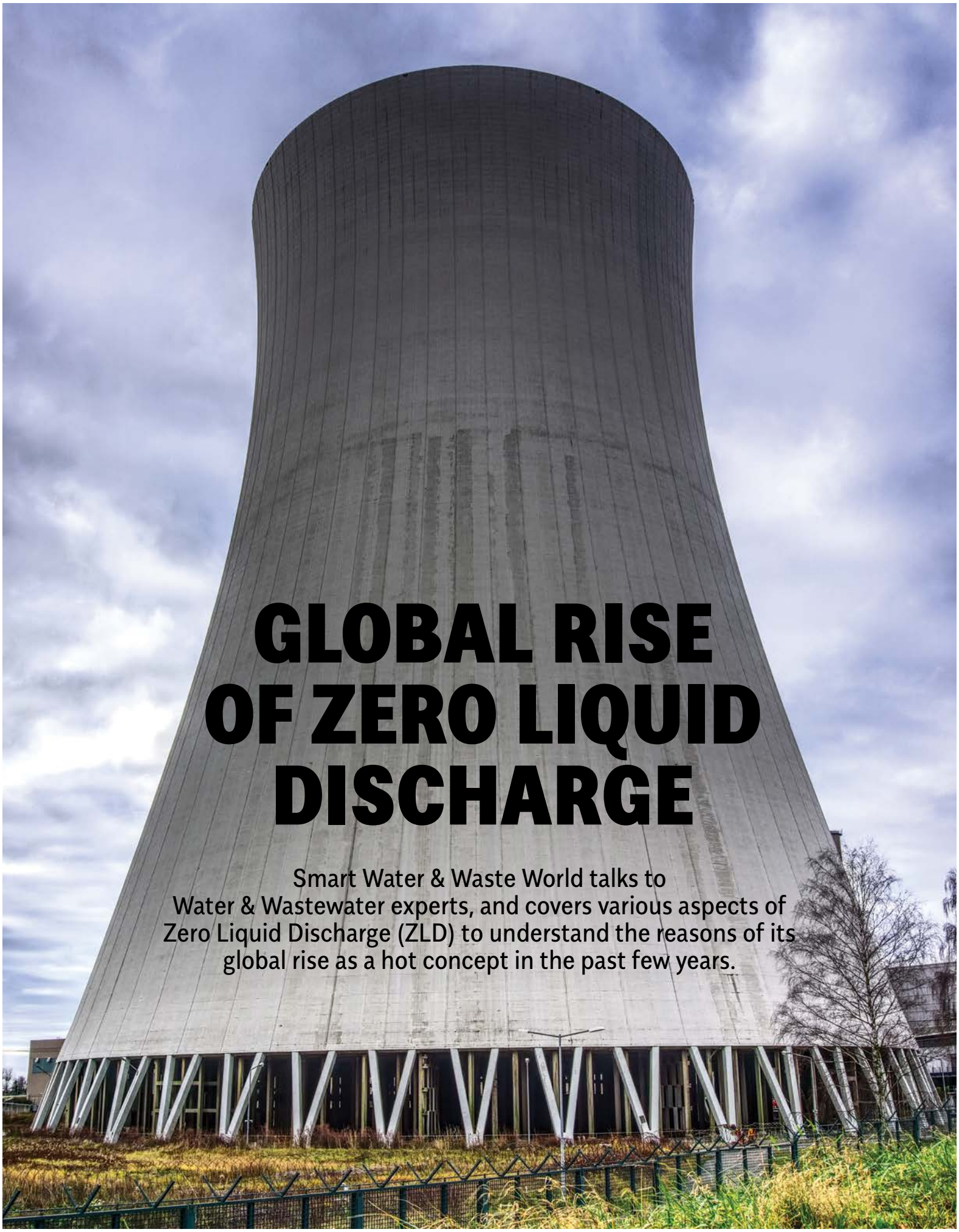
The Industrial Mesh division saw an increase in sales revenue of 7.1 percent on the previous year. The key drivers of this were the automotive industry as well as various applications in the field of solid-fluid separation. "We are often asked whether the changes in the automotive industry lead to us receiving fewer orders," says Stephan Kufferath. He continues: "Quite the opposite is true, as we are not part of the problem but part of the solution!" His brother and fellow Director, qualified engineer Ingo Kufferath, also sees GKD as being ideally equipped for the future of the automobile: "We've been working intensively on topics such as electromobility, driverless vehicles, etc. for a very long time and are involved as development partner in a number of key projects." In addition, the new product range of Porometric mesh achieved significant initial success in the crude oil industry and water filtration. For the current financial year, GKD has set its sights high in terms of expected sales for this three-dimensional filtration mesh, the performance spectrum of which considerably exceeds all meshes previously used in these applications.

With solutions that contribute to making the world healthier, safer, and cleaner, GKD's Process Belt division recorded an above-average increase in sales revenue of 11.2 percent in 2018. The major contributor to this development was the new production site in the USA, with which GKD significantly expanded production capacity for this business division in particular. GKD process belts are used the world over in areas such as environmental protection or hygienic applications - from diapers to food production. Sales revenue in the Metal Fabrics division, too, exceeded that of the previous year. The rise of 10.2 percent was also heavily influenced by the positive business development in the USA. The acoustic ceiling in the Museum of the Bible, Washington, paved the way for ceiling systems from GKD in the U.S. market. Yet the most successful system launches in the Architecture division in 2018 were roller shutters and doors. The Mediamesh transparent media façade system performed positively, climbing by 33 percent compared to the previous year. A great example of this is the interactive media façade at Stanford University.

High Expectations

For the current fiscal year, GKD expects a further significant rise in Group earnings despite increasing uncertainty in the global economy. For the first time, the company is aiming for sales revenue in excess of 100 million euros in 2019. "By driving internationalization hard in the last few years and through attractive market opportunities for our new product developments in all business units, we are well equipped even for difficult conditions," says Ingo Kufferath of this goal.

As a privately-owned technical weaver, GKD - Gebr. Kufferath AG is a market leader in metal, synthetic and spiral mesh solutions.



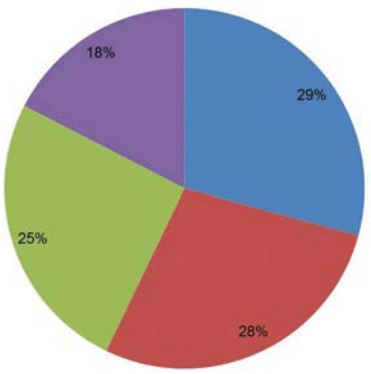
GLOBAL RISE OF ZERO LIQUID DISCHARGE

Smart Water & Waste World talks to Water & Wastewater experts, and covers various aspects of Zero Liquid Discharge (ZLD) to understand the reasons of its global rise as a hot concept in the past few years.

Zero Liquid Discharge (ZLD): A Frost's Perspective

Frost & Sullivan estimates that the global ZLD market is estimated to grow from USD 527 million in 2018 to USD 944.5 million in 2024 with a CAGR of 10.2%.

By Paul Hudson



Global ZLD Market: Revenue by Region, 2018 (Source: Frost & Sullivan)

Need for ZLD

Water stress and pollution has caused a significant impact on environment and economy across the globe. There is a rise in conflict due to the rise in domestic and industrial water demand on the back of rapid industrialization. Water pollution has severely degraded surface or groundwater quality in most urban regions. APAC region, especially countries like India and China are one of the most affected by water stress due to rapid industrial growth and lack of adequate resources to cater to the water demand and mitigate environmental impacts.

Factors like climate change and associated environmental impacts like high temperature and droughts have led to the dwindling of freshwater resources. The exploitation of freshwater resources like groundwater and lack of reliable surface water are significantly impacting socio-economic growth.

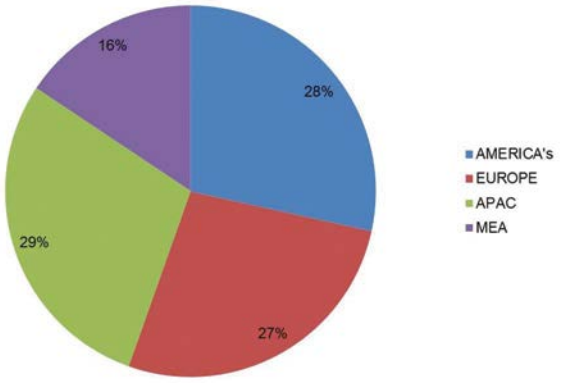
Reuse and recycle of water is now being considered as the most sustainable way forward. Technology evolution in the water industry has now enabled the reuse and recycle of almost any type of industrial or domestic effluent through Zero Liquid Discharge (ZLD) process, which involves the complete recovery of water and effective separation of sludge (biosolids).

ZLD solutions not only help in complete water recovery (for recycle and reuse) but also aids in recovery of valuable resources from the sludge such as salts which can be reused this further enables circular economy and sustainability. ZLD is now being explored and mandated for highly polluting industries across the globe. It has become an essential tool to reduce water demand and additionally it empowers resilience to climate change.

Drivers & Restraints

The key driver for ZLD across the globe is water stress. In the past decade, most countries have revised or amended regulations pertaining to effluent discharge. Regulatory requirements have become stringent and this has driven industrial end-users to adopt ZLD for compliance. Some countries have mandated ZLD for highly polluting industries such as Textiles, Chemicals, Paper & Pulp, Thermal Power generation, and Pharma situated in water-stressed regions.

High CAPEX has been one of the key challenging factors that have restrained its growth especially in developing countries. Others include high energy cost, need for customization as per industrial effluent quality, recovery of solids demand advanced treatment depending on the level of purity required and finally concerns over quality of reused water in pharmaceutical and food industries. Additionally challenges like inefficient stripping of effluents, high OPEX due to high rate of scaling and the need for frequent cleaning have also impacted its growth and adoption amongst potential end-users.



Global ZLD Market: Revenue by Region, 2024 (Source: Frost & Sullivan)

ZLD Process - Treatment & Technology

The key ZLD treatment process includes:

- Effluent treatment (Primary, secondary and tertiary treatment),
- Membrane filtration,
- Brine Concentrator,
- Evaporation/ Crystallization, and
- Recovery

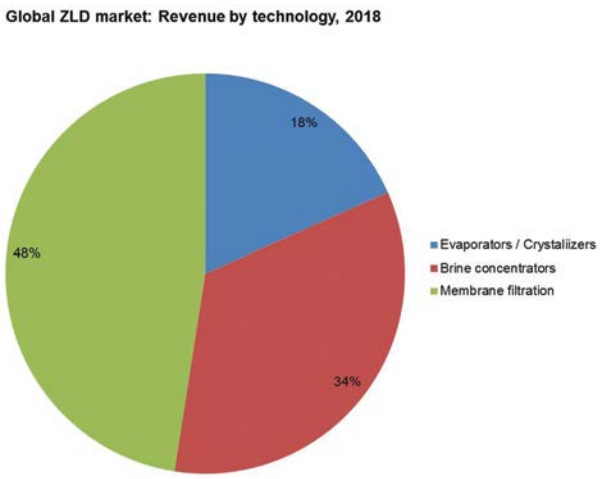
Tertiary treatment and membrane filtration helps to recover most of the water whilst evaporation and crystallization helps to recover the residual water and effectively recover the solids.

Reverse Osmosis is the most widely used membrane filtration technology other disruptive technologies include Forward Osmosis (FO), Electro Dialysis Reversal (EDR), and Membrane distillation. But most of these technologies are highly specific to certain types of effluents and which makes RO membrane filtration the most adopted treatment technology.

In the near future, innovative brine concentration technologies based on membrane or Humdification-Dehumdification (HDH) process could gradually replace Evaporators. Currently innovation and development of membrane material such as ceramic membrane and Chemical Resistant (CR) membrane is gaining significant attention for its capabilities to handle high fouling waste streams, high pH, and temperature.

Hybrid systems which could be multiple combinations of technologies such as Ion exchange, EDR, FO and RO is being increasingly explored and adopted for its efficiency and cost effectiveness.

New disruptions are taking place on the back of the digitalization of ZLD treatment. Companies like Berghof have developed B Smart membranes which are assisted by intelligent software that can optimize the operation and effectively reduce maintenance and chemical usage. In the next five years, we could be witnessing significant improvement in water and energy efficiency of ZLD systems due to system optimization through data analytics and software tools. Smart sensors could play a vital role in providing real-time data and visualization of the process which in turn would be analyzed for opportunities to fine-tune and optimize the system through advanced data analytics tools. Augmented reality (AR), Virtual reality (VR) platforms and associated digital twin solutions could significantly reduce CAPEX and OPEX by aiding design and real-time optimization of the system which would eventually result to in minimal or no downtime and drastically reduce chemical usage. Service-based business models could emerge in the back of digitalization which could also involve the remote operation. Other disruptions include the development of clean, green, and sustainable chemicals used to remove fouling and scaling in membranes.



Global ZLD Market: Revenue by Technology, 2018 (Source: Frost & Sullivan)

Global ZLD Market

Frost & Sullivan estimates that the global ZLD market is

estimated to grow from USD 527 million in 2018 to USD 944.5 million in 2024 with a CAGR of 10.2%.

APAC is the fastest-growing market. China and India are the key growth drivers. Thermal power plants, specifically, ZLD treatment for wastewater generated by FGD unit is expected to be the key driver in China whereas in India river cleaning projects such as Namami Gange and regulatory enforcement of ZLD for highly pollution industries will be the key driver. The revenues in APAC are set to increase from 25% in 2018 to 29% of the global revenues in 2024. Textile Industries, Thermal Power Plants, Pharmaceutical Industries, and Paper & pulp Industries are the key customers for ZLD in APAC due to high regulatory scrutiny and stringent discharge compliance requirements for these industries.

Membrane filtration technology is the most commonly used technology in the ZLD process, depending on the treatment required - the ZLD systems have a customized brine concentrator, evaporator and/or crystallizer.

Disruptive Innovations in ZLD: Case Study

Saltworks - Flex EDR System

Saltworks is one of the leading industrial wastewater treatment and ZLD solution provider. It is based in Canada and has recently expanded to new fast-growing markets like China.

Saltworks have innovated and developed Flex-EDR (Electrodialysis Reversal) system, which consists of IonFlux ion exchange membrane. The Flex EDR's key value propositions are:

- It is resilient to turbid wastewater streams and frequent backwash to remove biological fouling.
- It consists of a patented hardness blocker that protects the electrode and hence does not need chemical softening, and
- Advanced Process control that enables system optimization and efficiency.

These unique features positions Flex-EDR as an economical alternative to Reverse Osmosis which is the most commonly used filtration process for ZLD treatment.

The Flex EDR product line includes:

Flex EDR Organics: It desalinates produced water or wastewater with high organic content thus reducing the need for extensive pre-treatment,

Flex EDR Selective: It helps to selectively remove monovalent ions (eg. Chloride) It can extract salts form highly saline streams that are of high value, and

Flex EDRAmmonia: For wastewater systems that require removal of ammonia.

Saltworks has successfully piloted the Flex EDR system at the site of a Thermal Power plant in the USA. The Flex EDR was used to treat the wastewater that is generated from Flue Gas Desulfurization (FGD) unit. The Flex EDR was installed to selectively remove chlorides and thereafter the water was reused internally for the coal stack scrubber system. The Flex EDR is modular and hence it can be easily shipped, it has a low footprint and is easily scalable. The system is also fitted with sensors that enable operators to gather data and optimize the process on a real-time basis.

Gradient - Carrier Gas Extraction (CGE)

Gradient has developed and patented an innovative treatment system called Carrier Gas Extraction which is based on Humidification-Dehumidification (HDH) process. This system mimics the natural rain cycle and is an economical alternative to Evaporators. CGE has been successfully installed in a Thermal power plant in china to treat and recycle wastewater streams generated by the FGD unit. It has also been installed in Textile industries based in Tamil Nadu, India where it was mainly adopted for its cost-effectiveness over an evaporator for brine concentration and ZLD.

Conclusion

ZLD treatment systems have rapidly evolved and innovations are gradually improving its cost-effectiveness and sustainability. To mitigate water stress and meet water demand ZLD treatment could become the only way forward in water-stressed and water-scarce regions around the globe. Combination of various technologies (Hybrid) along with digitalization enabled by IoT based sensors would drastically improve efficiency. Reduction of energy consumption and economic viability has become a key focal point of innovation. Membranes will play a key role and may replace or reduce the dependence on energy-consuming crystallizers in the near future.

About the Author

Paul Hudson *is a Senior Research Analyst at Frost & Sullivan.*

Frost & Sullivan *is a research & consulting firm that helps clients accelerate growth. For over five decades, Frost & Sullivan has become world-renowned for its role in helping investors, corporate leaders and governments navigate economic changes and identify disruptive technologies, mega trends, new business models and companies to action, resulting in a continuous flow of growth opportunities to drive future success.*

APAC is the fastest growing market. China and India are the key growth drivers. Thermal power plants, specifically ZLD treatment for wastewater generated by FGD unit is expected to be the key driver in China, whereas in India, river cleaning projects such as Namami Gange and regulatory enforcement of ZLD for highly pollution industries will be the key driver. The revenues in APAC are set to increase from 25% in 2018 to 29% of the global revenues in 2024. Textile industries, Thermal power plants, pharmaceutical industries and Paper & pulp industries are the key customers for ZLD in APAC due to high regulatory scrutiny and stringent discharge compliance requirements for these industries.

ZLD: TECHNOLOGY DEVELOPMENT AND NATIONWIDE UNIFORM POLICY ARE THE WAY TO GO...

Sajid Hussain Inayath is the Chief Operating Officer in **Tamilnadu Water Investment Company Ltd (TWIC)**, responsible for its operations and water reuse business. **Mayur Sharma** talked to him about the current scenario of ZLD in India and the role his organization is playing in the projects involving ZLD technology.

Q. We are seeing a lot of interest in the evaporation and zero liquid discharge technologies globally. What are the reasons behind their increasing popularity?

Mr. Hussain: Increasing pollution of rivers, litigation by affected public and farmers, the threat of closure of industries by courts, increased pressure on the state and central regulatory agencies, difficulties in complying with regulatory standards for treated effluent discharge, inability to maintain or obtain valid consent-to-establish or consent-to-operate from the regulatory agencies, the rising cost of freshwater and finally water scarcity are the reasons for the increasing popularity of ZLD in India.

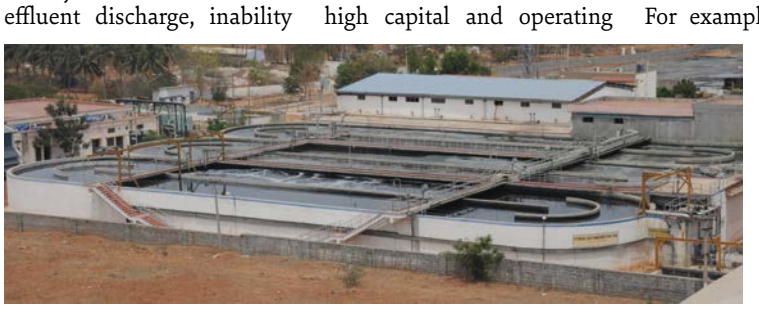
Unfortunately, the reasons are in the order of priority I have stated. Same is the situation in China. Other developing countries, with a focus on manufacturing, are becoming more aware of this situation only now. In developed countries, it is more to do with brine management in oil & gas industries to comply with their regulatory requirements.

Q. How is the Indian industry accepting ZLD technology?

Mr. Hussain: ZLD is not yet part of the environmental standards under the Environment Protect Act. It is, therefore, not a law that can be enforced by the regulators. Therefore, the adoption of ZLD has been slow.

As stated earlier, difficulties in achieving treated effluent discharge standards and the threat of court closure is driving the adoption of ZLD technology in India. The main deterrent is the high capital and operating costs of the ZLD systems. There have been significant improvements in technology and energy requirements resulting in lowering of costs within the last decade, this will reduce further with more innovations in the pipeline and will promote the adoption of ZLD. Typically 50% of the capital and operating cost of ZLD is towards the management of reverse osmosis brine rejects through thermal evaporation. Similarly, 50% of the operating expenses is towards energy (electricity and steam). With technologies focussing on increased recovery through membrane processes, the cost and energy requirements of RO brine management will drop significantly. Use of captive power plants with co-generation, use of renewable energy options like solar, etc will also reduce energy costs. Some of these technologies have already been piloted successfully and large-scale implementation is already on. It must be remembered that the recovery of water and salts can reduce the operating costs of ZLD.

Another significant issue is the 'transfer of this additional cost of ZLD' to the buyer and the ultimate customer. For example, a leather tanner producing finished leather or textile dyer producing dyed fabric are the 'polluters' in the value-chain in manufacturing of leather goods or garments. These tanning/dyeing units need to bear the additional cost of pollution control through ZLD. Unfortunately, these are mostly small-scale, 'job-work' units and the additional cost of ZLD can be 12-15% on the finished leather or the dyed fabric and has a huge impact on their viability.



Overview of the ZLD CETP

This cost needs to be transferred to the manufacturer of finished goods, like on shoes, upholstery, garments, etc who are major exporters. Moreover, the additional cost of ZLD on the finished goods can be as low as 1 or 2%. However, with non-uniform application of ZLD standards within the country and the world, the goods manufactures are reluctant to buy the finished leather or dyed fabric with an additional cost of ZLD and look for lower-cost alternatives from neighboring industries or clusters that have not implemented ZLD and are, therefore, cheaper by 12 to 15%. This issue can be addressed through a proper policy framework for encouraging 'transfer' of pollution control costs through ZLD from the 'polluter tanner or dyer' to the goods manufacturer. Tax rebates, green labelling, and uniform ZLD standards are some possible interventions.

Q. What is the role of TWIC on the ZLD front?

Mr. Hussain: On the ZLD front, TWIC (Tamilnadu Water Investment Company Ltd) is a project developer and consultant providing solutions for polluting industries by just not just stoppage of discharge of effluents through the recovery of water but also recovery of resources from the wastewater including salts and chemicals. We have developed pioneering solutions for textiles, tanneries, pulp & paper, agro-chemicals, and recently in the fertilizer sector too. These are all unique first-of-its-kind without any precedent. These technologies are developed through R&D, demonstration of techno-commercial viability of the technology through piloting and finally we also deliver the promised performance through actual O&M. ZLD technology employs a host of wastewater treatment technologies that require professional O&M and we are proud that we have successful O&M contracts of such facilities for more than a decade. We are today advising several state governments across the country and also the central ministries like the Ministry of Textiles and the National Mission for Clean Ganga (NMCG).

We have helped develop the Integrated Processing Development Schemes (IPDS) which supports the implementation of ZLD through central and state grants to the extent of 75%, which is a significant step in promoting ZLD. We have also worked with other countries like Bangladesh, and have had technical collaborative projects with multiple technical universities in Germany and Australia on ZLD. In addition to this, TWIC is on the forefront with regard to project consultancy in the urban water, desalination, and lake/river restoration areas.

Reverse Osmosis Plant

Q. Tirupur is a textile cluster dubbed as the first in India to shift to 'zero liquid discharge' in a systematic manner. Can you elaborate on how it happened?

Mr. Hussain: The textile dyeing units in the town of Tirupur, state of Tamilnadu, in the South of India have had a serious environmental impact on the town, particularly the Noyyal River. Further to stringent directions by the honorable courts in response to petitions from the local farmers, the industry was forced to implement zero liquid discharge in a very short period in 2006.

The project was implemented at a cost of Rs. 10 billion for a combined capacity of 100 MLD for 18 Common Effluent Treatment Plants (CETPs) catering to about 244 dyeing units in the industrial town of Tirupur. Faced with the challenge and lack of technology and experience in ZLD worldwide, particularly for a textile dyeing cluster, the project implementation ran into severe problems; particularly with thermal evaporation of reverse osmosis reject brine, leading to the closure of all the dyeing units in Tirupur under the court orders in 2011-12. Faced with this daunting task under adverse circumstances of court closure and lack of faith on viability of the technology for zero liquid discharge, the TWIC team developed and implemented a unique technology for reuse of treated liquid brine for reuse of over 70% of the salt in the wastewater along with reuse of 98% of recovered water by a cluster of dyeing units connected to a central wastewater treatment facility.

RO Skids

The Tamilnadu state government took the initiative and supported the cluster with an interest-free loan in 2012 to support the implementation of this 'brine reuse' technology. The technology was first demonstrated at Arulpuram Common Effluent Treatment Plant (CETP), a 5.5 MLD central treatment facility catering to a cluster of 12 dyeing units for which permission was sought out from the government to reopen the CETP and the connected dyeing units to do a trial demonstration of the technology. This technology not only demonstrated high recovery of water but also recovery of salts for reuse within the dyeing industry, thereby, moving towards 'zero waste discharge' and not just 'zero liquid discharge'. Based on the success of the technology, the remaining 17 CETPs and the remaining 232 dyeing units were reopened with the implementation of ZLD technology majorly based on the 'treated brine reuse' and recovery of salts, paving the way for the revival of the around 3 billion USD Tirupur textile cluster.

Seeing the possibility of a revival of the cluster, the central government too pitched with an additional support to rescue the industry from financial distress. I would like to briefly summarize the achievements of the ZLD CETPs as follows:

- No discharge to land or river resulting in stoppage of pollution.
- Higher compliance than the present and future National EPA standards.
- Recovery of 95-98% of high-quality water: Around 16.5 billion liters was saved annually, and it is to be noted that since re-opening of the CETPs in 2012, around 100 billion liters of water has been saved. This drastic reduction in demand for freshwater simply means more water is available to farmers and domestic demand in this drought-prone, water-stressed district of Tirupur.

- Huge savings in water bill - savings were around 18.35 million USD per annum.
- Water conservation in dyeing units - water consumption reduced to 40 to 50 liters per kg of fabric.
- Recovery of 70 to 80% salt as sodium sulphate and as brine, purchase of fresh salt from the market is avoided. Saves approx. 20% of the ZLD costs.
- Financial viability proven - but need to improve national/ regional competiveness (gross 12%, net cost additional 5%).
- International recognition and awards from the UK and the USA.

The one major highlight in all this is that pollution monitoring is no longer confined to the state and central regulatory agencies but has empowered the layman or the common man. No more requirements testing of 'treated effluent' in laboratories to confirm violations, mere discharge of wastewater from the industries premises is a violation that any layman can easily identify and record, resulting in the immediate action of stoppage of production until things are set right. Perhaps more violations have been recorded after implementation of ZLD than before. This, I feel, is a significant change ZLD has achieved in the cluster.

Q. You have said in the past that if we look at the cost of ZLD wastewater treatment, it is perhaps cheaper for the industrial units to just extract groundwater for their use. ZLD is constrained by high-cost and intensive energy consumption. What are the practical drivers and incentives for ZLD then? And how can we overcome this problem in the long run?

Mr. Hussain: To clarify your question, what I meant was that if groundwater extraction is freely allowed and the cost of fresh water remains unrealistically low, then there will be no incentive for recycling or ZLD. The cost of fresh water has to be priced right and usage of groundwater regulated. In Tirupur, the cost of fresh water for the industry is at Rs. 78 per KL and, therefore, recovery of water through ZLD reduces the cost of purchase of fresh water from municipal sources.

The main drivers for ZLD today are:

- **Regulatory Pressure,** as I said earlier, is a main driver - compliance of EPA for treated effluent discharge standards is difficult to achieve at the secondary treatment level. I am not talking just about the TDS standards of 2100 mg/l, achieving even 250 mg/l of COD standards at secondary standards is difficult. This can easily be confirmed from the CETP data put-up with CPCB and the various state PCBs. Of course, there is not much data on individual ETPs. This means you need tertiary treatment and advanced oxidation processes to achieve mere discharge standards. Why would anyone spend so much on these advanced treatment technologies at high-cost and discharge into river or sea? Therefore, recycling and reuse make better sense than just discharge in order to comply with EPA standards. More importantly, the state of rivers across the country due to Industrial pollution (and also municipal pollution) will result in greater activism from the public and farmers, forcing this issue further.
- **Water Scarcity** is another significant driver and everyone knows the situation across the country and I don't need to throw in data here. One significant incident I would like to highlight is the one during the drought year of 2014-15 in Tirupur, when even drinking water was being supplied to residents only on alternative days. However, the dyeing industry, which is a water-intensive industry, continued to run during the drought period due to recycling and reuse of its own wastewater due to implementation of ZLD. The industry appreciated its own efforts even more after this incident. Compare this with an earlier drought in Maharashtra where losses to the tune of over Rs. 90,000 crores was reported in the newspapers due to production losses caused due to water shortage.
- **Water Economics** is the third driver - as explained earlier, the cost of fresh water is priced unrealistically low across the country, and this needs to change. The new groundwater extraction rules may help to some extent. If the cost of water is significant, the industry will look at recycling and reuse.

Q. The Indian government's river rejuvenation initiatives like 'Namami Gange' have constantly pushed the demand for ZLD in past few years. What is your take on it? What are the practical challenges for the industrial areas situated near the rivers?

Mr. Hussain: It is to be understood that the 'treat-and-discharge model' has failed completely in protecting our rivers. Unless there is a paradigm shift in policy which prohibits discharge into rivers, the quality of our rivers will not see a major change. This is not just for the industrial ETPs but also for the STPs as well. We are only talking of our rivers and lakes, what about the sea and lands that are silently getting polluted? When will its actual impact be understood? I think it is time we implemented the 'treat-and-reuse model' with the revision of EPA standards for the river, marine, and land discharges.

Q. In past, exporters based in Tiruppur and Karur in Tamil Nadu had expressed that they had a disadvantage due to the zero liquid discharge (ZLD) norms stipulated by the state government. The norms pushed the cost for the units located in both the places by 15%, it was said. How can we overcome such challenges? Do we need similar norms nationwide - in all industrial clusters to make a level playing field?

Mr. Hussain: There are two ways to overcome these challenges. One is through technology development to drastically reduce costs and the other is through uniform nationwide ZLD policy.

It is only a decade since the adoption of ZLD in clusters like Tirupur and Vellore. Within this decade, there have been several improvements in technology, reducing the costs. And I think, with more time, we may see the costs drop drastically, the trend is clear to me. A nationwide uniform ZLD policy will also give a significant push to technology development, in addition to ensuring level playing field. In addition to the adoption of ZLD standards, I have already mentioned the need for a policy framework through incentives. Non-uniform adoption of ZLD threatens to make clusters adopting ZLD unviable.

One of the major arguments against uniform adoption of ZLD standards, ironically from the regulatory agencies, is that the high costs of ZLD will kill the industry and, therefore, options like river discharge should be allowed wherever dilution volumes are available or permit sea discharge wherever the cluster is close to the sea. However, the ground reality of such rivers and sea is for all to see.

My analysis of this situation is that most of these polluting industries shifted to India and China in the 60-70s due to the issues of pollution costs and also labor costs. Technologies like membrane technology were not developed (as it is today) and they could not address the issue, resulting in shifting of industry and jobs to Asia. Today, the widespread pollution has forced the public and farmers to approach the courts resulting in closure or threat of closure resulting in loss of jobs and incomes. The courts seem to have taken over the role of regulatory

Multiple Effect Evaporators

Sodium Sulphate Salt Production from the ZLD CETP

agencies. If this continues, most of the industries may shift to South-East Asia or African countries and this trend is already observed in both India and China. If we do not tackle the issue of pollution, loss of manufacturing jobs are on the horizon which a populous country like India (which is yet to achieve economic standards like China) can ill afford. A cursory look at all our Industrial clusters will show this for a fact. Almost all clusters are seen to have major ongoing environmental litigation, facing closure or threat of closure or reduced productions. If our traditional clusters get rid of such pollution issues through ZLD, we may be able to double jobs and growth rates.

Q. What are the potential environmental impacts of ZLD (greenhouse gas emission and generation of solid waste, etc)?

Mr. Hussain: The high carbon footprint of ZLD to high-energy consumption is a significant issue and needs to be addressed. As I explained earlier, higher recoveries through membrane processes to reduce or eliminate thermal evaporators are already a possibility. Use of renewable energy, like solar, is also on. For example, we have worked on membrane distillation with solar thermal systems. Such ZLD systems have a lower carbon footprint than even conventional 'treat-and-discharge' treatment systems.

With regard to solid waste, we have lime sludge and biological sludge wastes, similar to any conventional ETPs. The lime sludge being sent to co-processing in cement industries is now an accepted practice in Tamilnadu. We have proposed briquettes for use in boilers for bio-sludge, which is still pending approvals.

The issue with ZLD plants is the mixed salt waste, which is a serious disposal issue. The tannery clusters do not recover salts and the entire salt is a waste salt and is stored. The textile clusters recover around 70% for reuse within the dyeing industry and the remaining 30% is mixed saltwaste. We have developed technologies to recover sodium chloride and sodium sulphate salts and have implemented in one CETP which can recover salts completely. Complete recovery of salts in all sectors will avoid the generation of mixed salt waste in ZLD facilities of the future. The salt separation and avoidance of any mixed salt waste for disposal is already being proposed and will soon become the norm.

Q. What are the research-needs you think are significant for the future, to improve ZLD systems even further and make them sustainable?

Mr. Hussain: Technologies that can reduce energy consumption, processes that can separate individual salts to high-purity, produce alkalis and acids for reuse, and technologies that can use renewable energy are some areas of research to make ZLD more sustainable.

Q. Finally, can you please mention some of the best projects of ZLD implementation which have impressed you in the recent past?

Mr. Hussain: I think the best ones are still in India because we also recover salts. Other than the Tirupur textile dyeing cluster's ZLD CETPs, I am impressed with the RANITEC leather CETP in Ranipet. I am not aware of any similar facilities abroad other than in the gas industry and may actually be ignorant.

Disclaimer: The opinions expressed in this story are the person's own, in his personal capacity, and do not necessarily reflect the view of TWIC.

Sajid Hussain has over 27 years' experience in Industrial Wastewater Engineering. He played a key role in the revival of Tirupur dyeing cluster, through development and implementation of a unique 'brine reuse technology' for achieving ZLD norms for textile dyeing effluents, winning several international awards from GWI-UK, WateReuse Association, USA, etc. He has developed ZLD technology for Pulp & paper and Leather Tanneries. He has been a consultant to many projects with national and international agencies like UNIDO, ECO-FEI Egypt, IFC World Bank, etc. He has done his M.Tech in Environmental Engineering (Gold medallist) and Environmental Toxicology.

A Closed Loop Cycle of Water with No Discharge

Archis Ambulkar is an internationally renowned environmental expert with significant contributions to the water sector. He is the author of the book "Guidance for Professional Development in Drinking Water and Wastewater Industry", published by the International Water Association. He has made key contributions towards Oxford University's Research Encyclopedia and Britannica Encyclopedia sections. **Mayur Sharma** recently interacted with him about the theme of this cover story - ZLD.

Q. What is a Zero Liquid Discharge (ZLD) system?

Mr. Ambulkar: Zero liquid discharge system, commonly abbreviated as ZLD, is an evolving methodology aimed at reducing the system's liquid waste discharges to nil. It mainly focuses on industries and manufacturing plants that generate spent water. The technique involves lowering the facility's wastewater releases, recovering and recycling water, and converting contaminants into solid waste for landfill disposal or reuse. Reclaimed water from ZLDs can be used for industrial water supplies, landscape irrigation, and other applications. In short, "zero liquid discharge" concept is a closed-loop cycle of water with no discharge. ZLD is gaining popularity due to its eco-friendly approach, water-saving potential, resource recovery opportunities, and reduced waste disposal costs. In addition, these units can help to meet stringent industrial wastewater discharge regulations and permits. Further, in-house ZLD plants can cut down on greenhouse gas emissions associated with waste transportation, promote sustainability and minimize the industry's overall environmental impacts.

Q. Can you discuss ZLD technologies and processes in brief?

Mr. Ambulkar: ZLD systems are a combination of pre-treatment, conditioning, treatment and recycling processes. Technologies like reverse osmosis, ultrafiltration, evaporation/ crystallization, evaporation, electrodialysis, and others are getting recognized as alternatives for zero liquid discharge systems. While many ZLD processes are established, others are still evolving. Selection of specific technology or a combination of technologies depend upon the type of facility, wastewater flows, contaminant characteristics, treatment goals, footprint requirements, and expected costs. A well-designed and efficient ZLD plant can manage variations in wastewater flow and pollutants concentration during the day to day operations. It can achieve maximum water recovery (total or near-total recovery) for reuse. The system can also convert contaminants into dry solid cakes that can be disposed of, recovered and reused or sold as quality products.

Q. Any thoughts on the applicability and global emergence of ZLD industry?

Mr. Ambulkar: The ZLD concept surfaced a few decades back. With changing regulations, rising water crisis and increasing waste disposal costs, the emergence of zero liquid technologies has been a natural outcome for industries. On the global scale, industries use about 20 percent of total water withdrawals and are one of the major water consumers within the societies. To meet the growing challenges, industries are making conscious efforts towards water use optimization, recycling, and reuse. ZLD is one step forward that considers total recycle with no liquid waste.

ZLD serves as a promising option for sectors like oil & gas industry, chemicals and petrochemical plants, power industry, mining, automotive, pharmaceutical, semiconductors, and many others. Sustained efforts by researchers and practitioners to develop ZLDs are slowly paying results. Competition for ZLDs is building and many established national and international firms are entering the market as well as providing products and services related to zero liquid discharge. Several technologies are in the research and development stage while others have become full-fledged technologies.

Overall, ZLD has become a global phenomenon. As of today, several installations are already in place and yielding results. The United States has many industrial ZLD installations, with major plants in the power sector due to stringent regulations. Countries like India and China, with rapid urbanization and economic developments, are implementing stricter regulations and moving industries towards ZLDs to cope up with water scarcities. Other regions of the world such as Canada, European Countries, Australia, the Middle East, and other nations have seen a steady increase in the ZLD plants. These global trends are commonly dictated by water status in the region, regional regulations, awareness as well as ZLD plant capital and operational costs. Given the present scenario and looking into the future trends, the market for ZLDs is wide open and bound to grow significantly.

Q. What kind of impact ZLD systems will have on the water sector?

Mr. Ambulkar: Water scarcity is one of the gravest challenges faced by our generation. So many communities around the world are experiencing the worst nightmare of not have enough water even for basic needs. Governments are struggling and taking steps to utilize every possible water drop available. While the scope of ZLD is limited, it still has a significant potential for boosting water conservation efforts and making a visible difference within the community. Reuse and recycling mantras of ZLDs will serve as a boon towards water management. Lesser water use by industries can reduce the burden on water extraction from resources. These water savings can then be used for other domestic and agricultural uses. This advanced technique is futuristic, ahead of time and capable of providing sufficient flexibility in water use for offspring. Zero liquid discharge systems will surely have a long-lasting and positive impact on water use.

Q. What are the research-needs you think are significant for the future, to improve ZLD systems even further and make them sustainable?

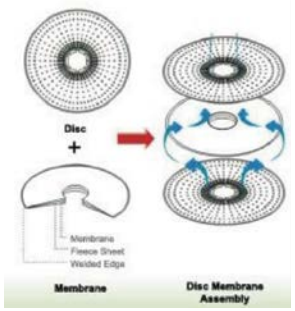
Mr. Ambulkar: ZLD industry is transitioning and expanding at a steady pace. Considering its potential applicability in varied sectors, still a lot more needs to be done in terms of research and development. Along with research, extensive pilot-scale studies are important for establishing technologies. Emerging ZLD systems need to develop a comprehensive scientific, technical and operational database. Also, adaptation to site-specific conditions needs to be studied thoroughly. Today, one of the visible challenges associated with ZLD is its high initial set up cost and operational expenses. However, noncompliance consequences and wastewater disposal expenses can outweigh ZLD installation costs in specific cases. Footprint requirements for ZLD units is another prominent area that needs further advancements. In terms of operations, some of the key challenges are related to membrane fouling, scaling, solids build-up and corrosion. Research is needed to manage these issues effectively. Demand for skilled personnel with specialized training and knowledge add to the ZLD requirements criteria. Finally, past experiences and challenges faced will drive the future research demands to identify priority areas and make the system more affordable and sustainable.

Considering the advantages that ZLDs offer, it is worth to invest time, money and efforts towards establishing these technologies.

ZLD: A Game Changer in Industrial Wastewater Management

In this case study, we have highlighted the performance of energy-efficient Rochem products such as PT-RO and WHE for ZLD in the industrial wastewater.

By Girish Thorat



Hydraulic Flow over Individual Membrane

Zero Liquid Discharge in India

The increased pressure from pollution regulatory body of India - CPCB (Central Pollution Control Board) and water scarcity have led many industries to re-visit the need for greener process technologies, adopt efficient wastewater treatment systems and to strictly monitor adherence to discharge norms. Recycling of maximum quantity of water back to the industries and progressing towards Zero Liquid Discharge (ZLD) is now definitely the need of the hour.

Disc Tube Module

ZLD allows extraction of important resources back from the waste. Regardless of an organization's motivation to aim ZLD, the results depict good economics, corporate responsibility, and environmental stewardship. With an internal ZLD process installed, the cost can be significantly reduced, more water is reused, and more resources can be extracted from the waste.

In this case study, we have highlighted the performance of energy-efficient Rochem products such as PT-RO and WHE for ZLD in the industrial wastewater.

Plate Tube - Reverse Osmosis Systems (PT-RO)

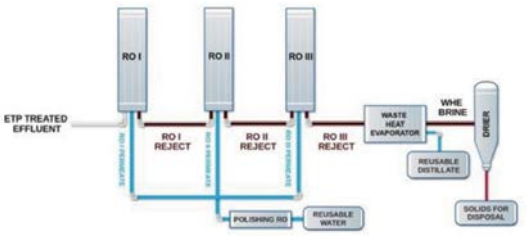
The plate tube membrane is specially designed for difficult and high concentration wastewater treatment with exceptional stability and high performance. The anatomy of the module makes the wastewater treatment highly efficient with its plate and frame structure.

Advantages of Rochem PT Module Membrane Systems

- Simplified and lower pre-treatment
- Ability to handle higher COD/BOD, SDI, turbidity streams compared to conventional technologies
- Consistent and high recovery rates
- High reliability
- Consistent high-quality permeates
- High-pressure DT RO designs for further recovery from RO reject concentrates
- Lesser space requirement

Waste Heat Evaporator (WHE)

Waste heat evaporator is a compact and efficient way for evaporating water from wastewater that contains high levels of contaminants and corrosive constituents. An alternative to prevailing technologies predominantly using metallic evaporators, this technology comes at a dramatically lower lifecycle cost due to lower operating and maintenance costs.



Solutions Offered by Rochem

The WHE presents an opportunity to the industry of economical and efficient way to concentrate process streams and the brine from RO plants on wastewater.

Sr. No.	Parameter	Unit	Values
1	Overall Recovery	-	> 99%
2	Total Permeate Quality	m^3/day	> 199
3	Combined Permeate TDS	ppm	100-150
4	Solids for Disposal	kg/hr	47

Table 1: Rochem ZLD System Performance Metric

WHE does not necessarily require a fresh source of steam and can effectively use other possible sources of the low-grade heat efficiently for its operation. The system has the lowest electrical power consumption among current evaporation/concentration technologies including multi-effect evaporators.

The schematic process elaborates on the flow of waste heat evaporator that contributes big in the process of filtration.

Advantages of Rochem India's Waste Heat Evaporators

- Lower capital costs
- Safe operations
- Longer equipment life and lower maintenance
- Consistent and high-quality of distillate
- Process reliability
- Reduces equipment size and hence lowers footprint
- Low cost on structural supports
- Easier maintenance

Case Study

The Background

One of the leading Automobile companies in India was looking for sustainable ZLD solutions. Recovery of recyclable water was the prime objective due to acute water shortage in the area and stringent norms on water discharge.

- Source of the effluent: ETP treated effluent
- Feed capacity: 200 m^3/day
- TDS: 3500 ppm

Sr. No.	Parameter	Unit	PT-RO	WHE	ATFD
1	Power	KWH	3	5	5
2	Steam Equivalent	Kg/hr (@ 2.5 bar)	-	125	-
3	Cooling Water	m^3/hr (@ 1 bar)	-	3	1
4	Thermic Fluid	Kcal/hr (@250°C)	-	-	60000

Table 2: Utility Consumption of Rochem ZLD System

Conclusion

Typical ZLD systems, despite the varying recovery rate come loaded with operating costs and operational limitations. However, the use of Rochem products such as high-recovery Reverse Osmosis systems (PT-RO) and Waste Heat Evaporators (WHE) achieves sustainable ZLD and efficient water recovery.

About the Author

Girish Thorat *is the General Manager India at Rochem Separation Systems (I) Pvt. Ltd. Mr. Thorat has served in the Merchant Navy for 11 years before moving into the corporate sector. His current role is to drive the sales and marketing of land-based membrane systems in the industrial sector at Rochem Separation systems.*

Zero Liquid Discharge via Membrane Distillation: A Future Solution to Water Crisis

Zero liquid discharge (ZLD), as an ambitious water management strategy that intends to recover nearly 100% water for reuse and eliminate any waste liquid discharge, has drawn increasing attention in recent years.

By Dr. Kang Jia Lu, Jian Chang and (Neal) Tai-Shung Chung

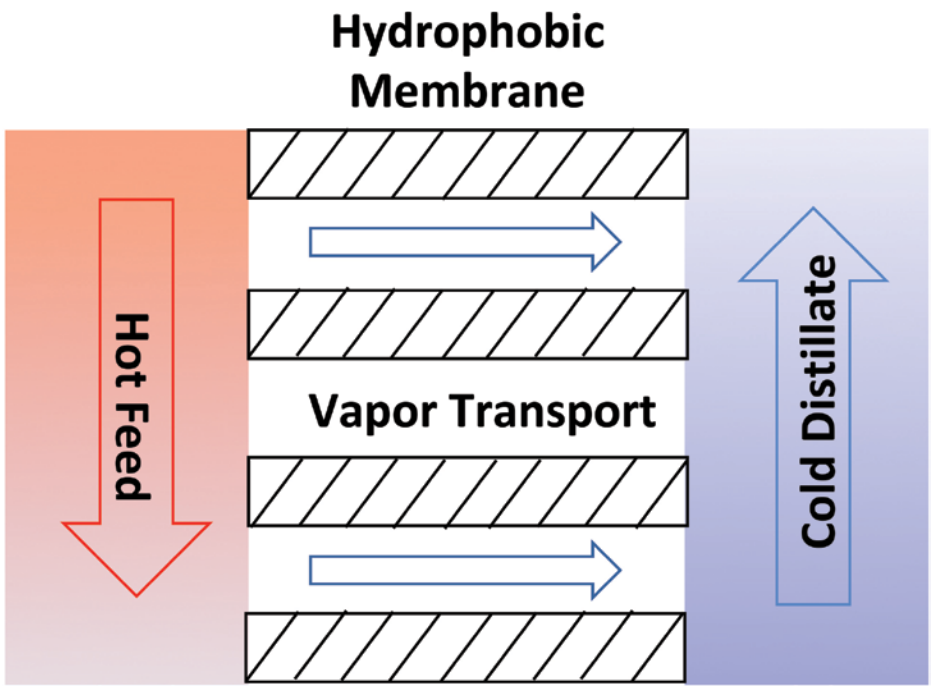


Figure 1: Vapor Transportation in Membrane Distillation

Introduction to Zero Liquid Discharge (ZLD)

Freshwater scarcity and wastewater pollution are becoming two of the most threatening global challenges with nearly 2.7 billion people having limited access to clean water for at least one month per year. Population explosion and rapid growth of the economy in the past few decades have posed even more stresses to the water security issue. Due to the rising water demand and the fast depletion of freshwater resources, the combination of water recycling and wastewater treatment is considered as a necessary approach to mitigate the global water scarcity and environmental pollution. Zero liquid discharge (ZLD), as an ambitious water management strategy that intends to recover nearly 100% water for reuse and eliminate any waste liquid discharge has drawn increasing attention in recent years. Traditional ZLD systems were based on a series of thermal processes such as Mechanical Vapor Compression (MVC), Multi-Effect Distillation (MED) and Multi-Stage Flash (MSF) to separate steams from solids. However, conventional technologies are energy-intensive, they also require large vapor spaces and need expensive construction materials such as titanium to prevent severe corrosion caused by high temperature brines. These result in high capital costs which greatly impede the application of ZLD on a large scale. Therefore, alternative technologies should be developed to achieve ZLD at lower capital investment.

ZLD via Membrane Distillation (MD)

MD, as depicted in Figure 1, is an emerging technology that brings new possibilities to the industrialization of ZLD. Similar to the aforementioned conventional technologies, the driving force of MD is the temperature-induced water vapor pressure difference. Therefore, it also has a theoretical rejection of 100% to non-volatile compounds and its driving force is less sensitive to the Total Dissolved Solid (TDS) concentration. On the other hand, unlike traditional distillation, hydrophobic membranes are required in MD as contact surfaces for water evaporation, which could significantly reduce the land occupancy due to the large surface area to volume ratio of the membranes. Moreover, common hydrophobic polymer materials such as Polyvinylidene Fluoride (PVDF) and Polytetrafluoroethylene (PTFE) are much more anti-corrosive compared to metals. Both advantages translate to the real saving of footprint and capital investment. In addition, MD typically operates at a much lower temperature of 40 to 80 °C compared to conventional distillation, thus (1) MD can be powered by low-grade energy sources such as solar energy or industrial waste heat, and (2) MD is less corrosive and has a smaller heat conduction loss than conventional distillation because a mild operation temperature would reduce the system corrosion and the heat loss to the surrounding. These characteristics will significantly lower the energy cost for MD.

In this article, several MD-based hybrid systems and their ZLD applications will be elaborated with aims to attract readers to explore more on this promising technology for ZLD.

Membrane Distillation-Crystallization (MD-C)

Membrane distillation is typically combined with a crystallization unit to achieve ZLD. As depicted in Figure 2A, MD is mainly used for water recovery while the crystallizer extracts value-added salt crystals from the MDretentate. As a result, one can harvest both ultra-high water and salts, or even achieve a ZLD state by returning the crystallizer brine to MD for the next cycle of water and salt recovery.

Design of Suitable Membranes

Hydrophobic membrane is one of the key components in the MD-C unit. An ideal MD membrane should have a reasonable flux, good thermal, chemical and mechanical stabilities, and a low tendency to be wetted and fouled by the feed streams. To fabricate this membrane, one must balance various structural and chemical parameters such as membrane thickness, pore size, and surface energy, etc. Taking membrane thickness as an example, scientists have to consider its contradictory effects on heat efficiency and transmembrane flux. Mathematical simulations have suggested the optimum thickness to be in the range from 50 to 100 μm. Similarly, an optimum pore size between 0.1 to 1.0 μm is recommended by membrane scientists to ensure a good anti-wetting property without sacrificing the transmembrane flux. Of course, other factors such as feed compositions, operating conditions, and separation agendas should be also considered in real designs.

Another challenge that cannot be underestimated in MD-C is the inorganic salt scaling. As pure water is extracted constantly, the salt concentration in the feed may increase continuously to its saturation concentration. Thus, membrane scaling, which leads to pore blockage and membrane wetting, is almost inevitable. To mitigate the scaling issue, some novel membranes with excellent anti-scaling properties have been developed. For example, Lu et al. found that a superhydrophobic Teflon® AF 2400 coating could effectively retard the scaling process because the low-surface-energy fluorinated coating material reduced the affinity between the membranes and dissolved salts. Moreover, manipulating operating pa-

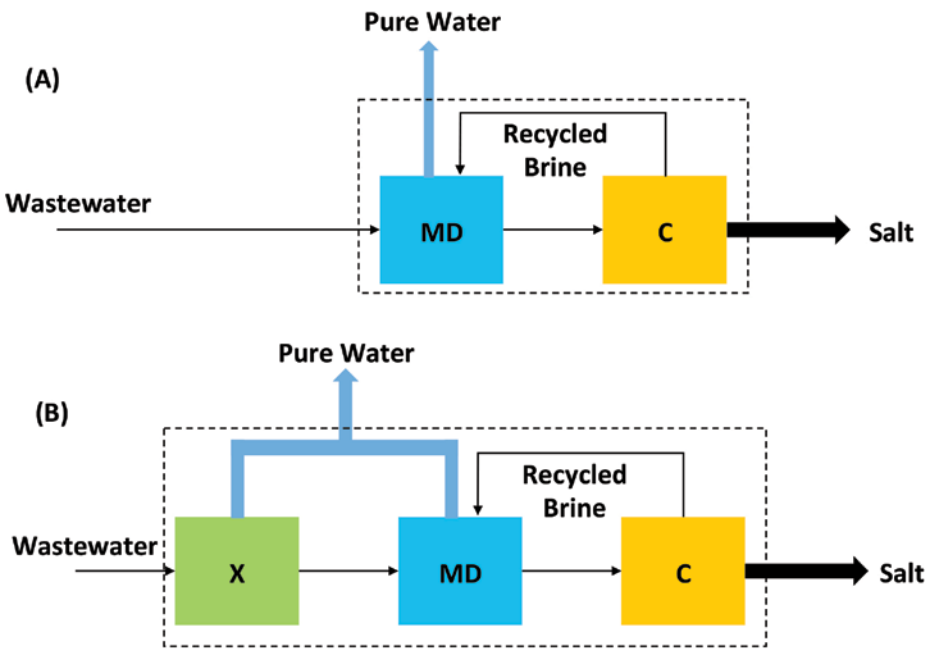


Figure 2: Schematic Diagrams of (A) MD-C and (B) X-MD-C

rameters by increasing the Reynolds number and reducing the Membrane Flux, and frequent washes have also been found to effectively reduce scaling.

Cooling Crystallization via Hollow Fiber Devices

To recover valuable salts from the concentrated brines, different crystallization methods such as evaporative crystallization and cooling crystallization have been developed. Among them, cooling crystallization via hollow fiber devices is receiving increasing attention in recent years. Zarkadas and Sirkar were the pioneers in proposing the Solid Hollow Fiber Cooling Crystallization (SHFCC), where they utilized impermeable polymeric hollow fibers as heat-exchangers to cool the brine below the saturation temperature. It could generate crystals with a nucleation rate of 2-3 magnitude order higher, a mean crystal size of 3-4 times smaller, and a narrower crystal size distribution than conventional crystallization methods. Moreover, the use of polymeric solid hollow fibers brings advantages such as ease of manufacturing and scaling up and great corrosion resistance. This technology has been successfully applied to recover valuable crystals such as paracetamol and KNO^3 from different liquid systems. Recently, Luo et al. developed a novel MD-SHFCC system for simultaneous production of water and salt crystals from NaCl brine solutions. The hybrid system exhibited an impressive pure water flux of 8 kg/m^2 h and a salt crystal yield of 64 g per kg feed.

X-MD-C

Despite of great potential of MD-C for ZLD applications, it still suffers from the intensive energy consumption because water recovery using MD involves evaporation and condensation of water. One of the solutions is to integrate it with other processes (denoted by X in Figure 2B) such as Reverse Osmosis (RO) and Freeze Desalination (FD) because these two processes consume less energy than MD-C when treating low salinity feeds. Nevertheless, they become uneconomic when recycling water from high salinity feeds due to either a drastic decrease in driving force or a rapid decline in product purity. Therefore, the recovery limits for RO and FD are around 50% and 30%, respectively. Since MD-C exhibits great stability in treating highly concentrated feed solutions, RO and FD can be considered as pre-treatment processes for MD-C to further recover water from the high salinity brines and thus achieve ZLD.

Several works have studied the feasibility of combining MD-C with pressure-driven membrane separation processes such as RO for seawater desalination. In all these studies, water recoveries over 90% were achieved by the hybrid systems while that of standalone RO could only reach 40-50%. Macedonio et al. conducted energy and economic analyses of different systems. They found the freshwater cost of the RO-MD-C hybrid system was about 0.74 \$/m^3 that was only half of the thermal desalination processes (about 1.5 \$/m^3). Therefore, if free thermal energy was available, the water cost of the hybrid system would be about 0.47-0.55 \$/m^3.

Recently, freeze desalination has also been integrated with MD or MD-C systems to reduce energy consumption. FD is a process that harvests pure ice crystals from the chilled saline water. It is more cost-effective than distillation because the latent heat of ice fusion is only 1/7 of that of water vaporization. In addition, the cryogenic energy for FD can be provided by waste energy. In Singapore, more than 6 million tons of Liquefied Natural Gas (LNG) is imported from overseas annually; the re-gasification process absorbs an enormous amount of energy, making LNG a perfect cooling source for FD. Our previous study showed that a 29.2% reduction of the total energy consumption could be achieved by the FD-MDC hybrid system if 30% of water was recovered using FD. Therefore, if free cold energy is provided from re-gasification of LNG, another 50% reduction of the total energy consumption is achievable. For an optimized ZLD desalination plant with a daily output of 2.52 kg of salt and 69.48 kg of water, 100% of its cooling energy can be supported by regasification of 207-kg LNG.

Conclusions

In conclusions, MD has a great potential to treat high salinity wastewaters, which is the key to realize ZLD. By coupling MD with crystallization and other membrane processes, not only water recovery but also energy efficiency will be further improved. The development of hybrid MD systems for ZLD will bring new possibilities to solve global water challenges.

About the Authors

Dr. Kang Jia Lu *is a research fellow at the Department of Chemical and Biomolecular Engineering, NUS. Her Ph.D. (under supervision of Prof. Chung) and Bachelor (1st honor) were also obtained from NUS. Her research interests include membrane fabrication, system integration, and simulation of various membrane applications, especially Membrane Distillation (MD). She was the leader of an MD project of S\$2,600,880. She has published 12 research articles in Water Research, Environmental Science & Technology, and other leading research journals. She also won the Faculty of Engineering 28th Innovation & Research Award of NUS in 2014, and Aseanian Membrane Society 11 New Member Special Award in 2018.*

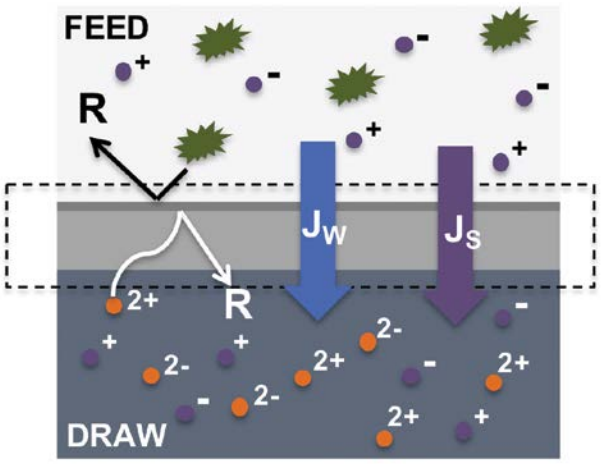
Jian Chang *is studying Ph.D. in Chemical and Biomolecular Engineering at the University of Pennsylvania. He earned a bachelor's degree of engineering with first-class honors from Nanyang Technological University. He completed his master's degree in engineering under the supervision of Prof. Neal Chung in the National University of Singapore. He studied seawater desalination by means of freeze desalination and membrane distillation. He has published 7 research papers in high-quality peer-reviewed journals. His research interests also include fuel cells and electrolysis.*

(Neal) Tai-Shung Chung *is a Provost's Chair Professor at NUS. He focuses on polymeric membranes. During 2005-2008, he was a Senior Consultant for Hyflux where he led and built its membrane research. He became a Fellow in the Academy of Engineering Singapore in 2012 and received IChemE Underwood Medal for exceptional research in separations and Singapore President's Technology Award in 2015. He was a highly cited researcher by Elsevier and Shanghai Global Ranking and received the Distinction Award from International Desalination Association in 2016. He is a highly cited researcher from Clarivate Analytics in 2018 with H-index = 98 (Scopus) or 112 (Google Scholar).*

Improved Resource Recovery from Zero Liquid Discharge (ZLD) Processes Using Novel Forward Osmosis (FO) Membranes

Since the industries account for around 20% of global freshwater consumption, and tend to be cash-rich in comparison to other freshwater consumers, the governments are increasingly tightening regulations on industrial wastewater disposal. Besides augmenting water supplies, wastewater disposal limitations have the added benefit of protecting aquatic environments.

By Mark Perry



Why are ZLD Processes on the Rise?

Water is no longer a given. Under great publicity, the 'Day Zero' was narrowly avoided in Cape Town during 2018 and now Chennai in India and many towns in Australia face the same crisis. When economic growth and public health face systemic risks, the economic burden of imposing stricter water treatment and water recycling regulations is dwarfed by the consequences of the status quo.

Since the industries account for around 20% of global freshwater consumption, and tend to be cash-rich in comparison to other freshwater consumers, the governments are increasingly tightening regulations on industrial wastewater disposal. Besides augmenting water supplies, wastewater disposal limitations have the added benefit of protecting aquatic environments.

Zero Liquid Discharge (ZLD) is the ultimate wastewater management that eliminates any liquid waste leaving an industrial plant, and - as such - also carries the highest price tag in terms of capital and operational costs.

According to the work by Elimelech and co-workers in "The Global Rise of Zero Liquid Discharge for Wastewater Management: Drivers, Technologies, and Future Directions", countries at the forefront of imposing ZLD regulations include the United States, China, and India. Whereas the power sectors are the main contributor to the ZLD markets in the United States and China, the textile industry is one of the main drivers in India's ZLD adoption.

The Potential for Lowering the Operating Cost of ZLD

Traditional ZLD processes are based on water evaporation and are therefore exceedingly energy-intensive. Typically, Mechanical Vapor Compression (MVP) evaporators use 20-25 kWh/m³ of high-grade electric energy to reach brine concentrations of 250,000ppm. In the last stage of ZLD, brine crystallizers use upwards of 70 kWh/m³.

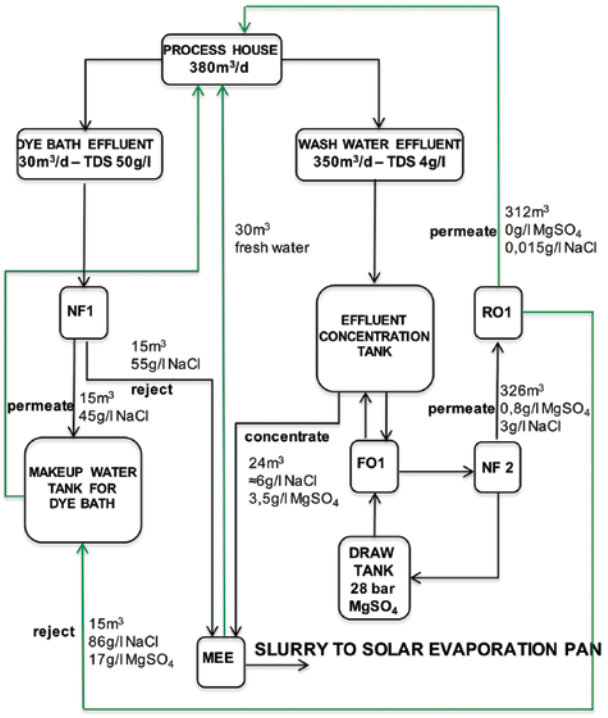
The final stage of evaporation is largely unavoidable hence strategies for lowering the operating cost of ZLD focus on brine pre-concentration to reduce capacity demand for evaporators and crystallizers. In comparison, membrane-based Reverse Osmosis (RO) processes consume 2-3kWh/m³ and, therefore, represent an excellent option for energy reduction of ZLD processes. Having said that, RO processes are limited by brine concentration and become less feasible above 70,000 ppm.

Hence, a window of opportunity exists for low-energy technologies capable of concentrating brines from 70,000 ppm to 250,000 ppm. A variety of membrane-based technologies have shown potential in this ppm-range, including Osmotically Assisted Reverse Osmosis (OARO), Membrane Distillation (MD), Electro-Dialysis (ED), and Forward Osmosis (FO). The remainder of this article will focus on how FO can be utilized to improve ZLD ROI.

The Slope of Enlightenment

Forward osmosis technologies have always been a favorite among membrane researchers. But it is fair to say, that the commercial FO field took a hit - and experienced some disillusionment - when it became clear the technology would likely never revolutionize seawater desalination.

Jeffrey R. McCutcheon's recent work "Avoiding the Hype in Developing Commercially Viable Desalination Technologies" aptly describes how the use of forward osmosis for seawater desalination has followed Garner's hype circle and currently resides somewhere in the region between the "Trough of Disillusionment" and the "Slope of Enlightenment".



- Makeup Water: 8m³/d
- Makeup Salt (NaCl): 930kg/d
- Draw Replenishment (MgSO4): 344kg/d

System Summary:

- Total Wash Water Demand: 350m³/d
- Total Dye Bath Water Demand: 30m³/d
- Total Salt Demand in Dye Bath: 2900kg/d
- Total Salt Demand in Wash Water: 0kg/d
- Recycled Wash Water: 342m³/d
- Recycled Dye Bath Water: 30m³/d
- Recycled Dye Bath Salt: 1970kg/d
- Volume to be Treated by MEE: 39m³/d

Economical Parameters	NF/RO/MEE	FO/NF/RO/MEE
Total System Cost (USD)	447000	671000 (+50%)
Daily CAPEX Cost (USD)	123	184
Daily O&M Cost (USD)	502	427 (-15%)
Daily Cost of Draw Solution (USD)	0	72
Daily Water Revenue (USD)	584	677
Daily Salt Revenue (USD)	169	413
Yearly Total Profit (USD)	47000	149000
Payback Period (Years)	9,5	4,5

Table 1

These days, surviving commercial FO players are now largely looking to occupy spaces where conventional RO is not applicable and where incumbent - and typically thermal based - technologies are much easier to beat.

Hence, commercialization of forward osmosis technologies is gravitating towards niche applications, which makes much more sense than aiming for the competitive and - from a membrane point of view - commoditized desalination sector.

How Can Forward Osmosis Improve ZLD Processes?

Contrary to traditional pressure-driven membrane technologies, forward osmosis uses chemical energy in the form of osmotic pressure to drive water transport across a semi-permeable membrane along the osmotic pressure gradient between feed (impaired water source with low solute concentration = low osmotic pressure) and draw (engineered solution with high solute concentration = high osmotic pressure) streams.

Being powered by an osmotic gradient, the energy requirement of water transport across a forward osmosis membrane is up to 90% less than that of reverse osmosis. Hence, FO has traditionally been viewed as a potential low-energy pre-concentration technology in ZLD applications. However, the low-energy ZLD argument only holds in the case where the engineered draw solution is of a sufficiently high osmolarity (above 300,000ppm NaCl equivalent) and can be regenerated through processes with low energy requirements (e.g. thermolytic regeneration using low-grade thermal energy).

In order to decouple the value proposition of FO from engineered draw solutions and regeneration methods, which may or may not turn out to be commercially viable on industrial scale, my suggestion is to start exploring the potential of FO to selectively recover valuable solutes from waste streams.

NF-Type FO Membrane Concept

Conventional FO membranes are designed to extract water from feed streams while rejecting virtually all other compounds. However, by tweaking the pore size of the FO rejection layer using the same piperazine-based chemistry known from Nano-Filtration (NF) membrane technologies, it should be fairly straightforward to achieve FO rejection layers with high rejection for divalent salts (e.g. $MgSO_4$) and low rejection for monovalent salts (e.g. NaCl).

What we end up with then, is an NF-type FO membrane capable of de-watering waste-water streams while simultaneously recovering monovalent salts (e.g. NaCl).

In addition, the NF-type FO membrane would likely enjoy a higher water flux and less concentration polarization.

Everything else equal, the added value from the recovered salt should improve overall system ROI. But how much improvement can potentially be gained?

I recently published a desktop study on ForwardOsmosisTech.com based on the work by Vishnu and co-workers ("Assessment of Field Scale Zero Liquid Discharge Treatment Systems for Recovery of Water and Salt from Textile Effluents." Journal of Cleaner Production 16.10 (2008): 1081-1089.).

The desktop study demonstrates clear operational and economic benefits of including an NF-type FO sub-system in ZLD treatment of wastewater from textile dyeing processes.

In conclusion, FO membranes capable of extracting both water and monovalent salts, hold potential for improving ZLD ROI.

Challenge Accepted?

Within today's conservative water industry, commercializing the forward osmosis technologies is very much an exercise in identifying applications with huge customer pains (the low hanging fruits), where current technologies are either not applicable, massively inefficient, or extremely expensive.

The use of forward osmosis for combined dewatering and resource recovery definitely seems to fit the bill. What remains to be done is for commercial players to start developing industrial NF-type FO membranes. Challenge accepted?

A window of opportunity exists for low-energy technologies capable of concentrating brines from 70,000 ppm to 250,000 ppm. A variety of membrane-based technologies have shown potential in this ppm-range, including Osmotically Assisted Reverse Osmosis (OARO), Membrane Distillation (MD), Electro-Dialysis (ED), and Forward Osmosis (FO). This article focuses on how FO can be utilized to improve ZLD ROI.

About the Author

Mark Perry *currently works at the Royal Danish Embassy in Singapore as Commercial Advisor where he mainly assists Danish CleanTech companies in their efforts towards capturing new business opportunities in Singapore.*

He has a CleanTech background from heading BD & Sales in Aquaporin Asia Pte Ltd, a Singapore-based CleanTech company. In addition, he has worked as a Membrane Developer, Project Manager, and Business Developer for Aquaporin A/S in Denmark.

He holds a Master's Degree in Physics and Cellular/Molecular Biology from the Southern University of Denmark and an Executive MBA from DTU Business.

He shares his years of experience in forward osmosis membrane development & commercialization on ForwardOsmosisTech.com - the go-to portal for general information on forward osmosis membranes, systems, technologies, and applications. Forward Osmosis Tech's vision is to become the leading independent branch specific portal in the FO field with a clear commercial and application-driven focus and a strong passion for promoting and facilitating open innovation, collaborations, partnerships, and co-developments.

Countries at the forefront of imposing ZLD regulations include the United States, China, and India. Whereas the power sectors are the main contributor to the ZLD markets in the United States and China, the textile industry is one of the main drivers in India's ZLD adoption.

Proven ZLD Systems Designed to Meet Today's Demands

Increased demands for water from municipalities, farmers and industries in arid areas are putting enormous pressure on limited water supplies which are particularly exposed to the effects of climate change.

By Matias Navarro

Producers across industries are pressured by competitors, stakeholders, and regulators to improve productivity, promote sustainability and protect the environment. Utilities, energy and other extractive sectors have been operating under these challenges for decades, particularly around their use of water in environmentally sensitive or water-stressed areas.

Drivers of Demand

Stricter wastewater discharge regulations have mandated industries of all sizes to update the way they run their operations for quite some time. These tightening standards not only focus on improving the quality of the water released to the environment but also the quantities that can be discharged. For instance, the injection of wastewater deep underground has brought investigation and regulation because of concerns of increased seismic activity. This forces industrial facility operators and project developers to invest in advanced wastewater technologies that can reuse this wastewater to minimize withdrawals and limit discharges. Furthermore, activists and consumers are also increasing the pressure put on industries to be more conscious of their operating choices. In water terms, that means implementing reuse standards not only to comply with planning and permitting needs but also to avoid tapping into water sources or discharging pollutants that bring strong opposition to industry settling or expanding in many parts of the world.

Increased demands for water from municipalities, farmers and industries in arid areas are putting enormous pressure on limited water supplies which are particularly exposed to the effects of climate change. Water intensive industries such as mining, power generation, and oil and gas extraction, need to do more with less and become more efficient with the water they take in. That means reusing what is inside the facility and reducing its freshwater intake.

Organics, volatile compounds, and constantly changing wastewater compositions can be increasingly challenging to be removed with conventional treatment programs which are also driving industry toward implementing zero liquid discharge (ZLD) systems. ZLD systems are designed to take wastewater through a series of physical, chemical and thermal technologies that produce two outputs: treated water that can be reused and, concentrated brine, which is further processed to separate salt crystals for disposal or beneficial use.

For instance, in the upstream energy sector, fracking wells require injecting large amounts of brackish water with proppants and other polymers to fracture the rocks underground. This volume of water, several times that of the oil and gas produced, requires advanced treatment to remove chemicals before recycling and completing the well. Another example is in the utility sector when cooling tower blowdown effluents are re-circulated more and more times in a closed loop. This creates more salinity and concentrations of biocides, scale-forming components, foam and corrosion inhibitors that condition the water to prevent bacteria, fouling and corrosion. Because these chemicals may harm aquatic species and ecosystems, they need to be removed before this wastewater is discharged to the environment. More treatment steps are necessary to degrade and remove ever more challenging species.

As a result of these forces at play, innovation in the

dissolved solids removal segment has brought a wave of emerging water treatment technologies: Electrodialysis Reversal, Reverse Osmosis, Forward Osmosis, Membrane Distillation, Humidification, Freeze Crystallization, Supercritical Precipitation, and others. Most new approaches, however, are not proven at industrial scale and their operation remains more energy-intensive than that of established, commercially mature, thermal evaporation systems.

How Does ZLD Work?

In broad terms, there are two general ZLD technologies that work to remove dissolved solids and impurities: thermal and membrane processes and frequently a combination of both in a hybrid form. The rapid advance of membrane technologies over the last few decades has been nothing short of remarkable. However, thermal systems based on established, proven technologies are often considered for more robust and versatile solutions to achieve concentrations near saturation or super-saturation in both complete water recovery and near (partial) ZLD which may dispose of evaporator concentrate by injecting it deep underground.

In general, a suite of technologies can be part of a ZLD approach including ion exchange, electro-dialysis, and softening. Reverse osmosis membranes, because of their cost advantages, flexibility and compact installation are invariably used. However, hardness, silica, and other potential scaling compounds must be removed to protect their integrity. Membranes also drive and enhance the system water recovery. This is defined as the percentage of the feed solution that may be recovered as product water. In other words, the lower the waste, the higher the water recovery.

Because typical high-hardness brackish water is particularly difficult to treat under elevated pH levels, the process starts by a pre-treatment step which typically consists of softening and clarification that targets the removal of suspended solids using lime, soda ash, caustic, and other chemicals to precipitate calcium and magnesium ions in the water. The main mechanism of coagulation/flocculation happens in a mixing reactor tank with these added chemicals to promote the aggregation of suspended solids. Once the solids have formed aggregates, separation can be carried out by settling or microfiltration membranes which remove much of residual hardness, silica, and other potential scaling compounds.

The pre-concentration step is completed by reverse osmosis membranes which divide the incoming flow in two ways. On one hand, the "permeate" stream is returned to reuse or treated for further purification using ion exchange or electro-deionization, a technology that uses an electrical potential to drive physical separation and achieve a demineralized quality of below 0.5 ppm without any chemical additives. On the other hand, the "reject" stream that feeds the falling film evaporators, also called brine concentrators, where the vapor is generated by heating across a large surface area.

Thanks to their efficient heat transfer technology, evaporators produce high-purity distillate, and achieve water recovery greater than 90%. Recovered water in a brine concentrator can be recycled in many plant processes such as cooling tower, scrubber makeup, or demineralizer feed water.

The pre-concentration steps achieve a key function: to reduce the volume to be thermally treated. This is important because the operation of this system requires concentrated flows to be efficient. The higher the recoveries in the pre-concentration step, the lower the costs of evaporation downstream, both capital and operational.

To complete the separation of the salts from the water, the brine produced by the evaporator feeds a crystallizer designed to further concentrate the reject volumes to the point of producing crystals. Crystallizers are designed to handle continuous crystallization of the various dissolved salts, which sometimes can be recovered as valuable by-products when equipped with solids dewatering and drying in a true zero liquid discharge system that delivers a product with about 90 percent solids content. These brine crystallizers typically are driven by live steam as in a Thermal Vapor Recompression (TVR) unit but in some cases they can use Mechanical Vapor Recompression (MVR) technology to recycle the vapor and reduce energy usage and operating costs.

What You Should Know About ZLD

Thermal separation units can be capital and energy-intensive. Because of this, the optimal ZLD system is designed for achieving zero discharge or specific waste reduction objectives that are unique to the needs of each facility.

Capital costs are usually associated with the need for tanks, heat exchangers, pumps, and other equipment to be fabricated in corrosion-resistant materials such as high nickel alloys (e.g. Titanium or Inconel) which can keep their long term integrity despite the aggressive operative conditions and high salinity environment.

Striking the right balance of operating costs requires comparing the relative costs of electric power and steam which will determine the sources of heat to drive the thermal separation units. To provide heat for the evaporation of the water in the brine, burning of natural gas through a boiler or steam generator may be required. For reference, the energy intensity of an MVR driven evaporator averages 20-30 kWh per cubic meter of brine while that of a TVR driven unit is about 45 kWh for the same volume. In fact, the stronger the brine concentration, the more the energy usage because the boiling point of brine rises with higher salt concentrations which needs for an increased pressure differential. Meanwhile, every cubic meter of brine treatment in a crystallizer takes around 100 kWh in a TVR driven crystallizer compared to about 55-60 kWh in an MVR driven unit.

> Innovation in the dissolved solids removal segment has brought a wave of emerging water treatment technologies: Electrodyalisis Reversal, Reverse Osmosis, Forward Osmosis, Membrane Distillation, Humidification, Freeze Crystallization, Supercritical Precipitation and others.

These estimates show substantial energy intensity. Without a doubt, there is room to decrease energy consumption in both evaporative concentrators and crystallizers. However, these figures compare relatively well against those of alternative emerging technologies which average consumption of over 200 kWh per cubic meter of recovered water.

Evaporative processes may also use larger amounts of chemicals (Caustic, Chelants, Dispersants, etc.) to keep the scaling species soluble. Chemicals do not guarantee scale-free operations but their cost is a protection against more expensive chemical or mechanical cleaning.

Control and Automation through Digital Tools

To ease the management of operating variables in ZLD systems and maintain optimal yield, safety, quality and efficiency, digital technologies enable teams to optimize operations in multiple ways including predictive maintenance and remote monitoring of assets. Cloud-based platforms such as Veolia's Aquavista™ harness data from sensors and analytics to enhance control and send alarms or alert operators of critical issues through an online dashboard accessible from any device. Specialized technicians can also gain visibility remotely thanks to the power of augmented and virtual reality that saves costs in field trips to train personnel, or troubleshoot and service equipment.

Real Needs Solved with ZLD

Power plants need massive amounts of water to supply their cooling towers. In Arizona in the arid American Southwest, a plant sends its wastewater, consisting primarily of cooling tower blowdown to a Zero Liquid Discharge (ZLD) wastewater treatment system. As the high quality "distillate" or recovered water is returned as makeup water for steam generation, and the balance returned to the cooling tower, the dried solids are trucked to a landfill. Thanks to ZLD, the plant maintains optimal operation while minimizing withdrawals and protecting scarce water sources.

Oil and gas production is associated with a brackish by-product stream called produced water which is difficult to reuse in fracking operations because it contains significant quantities of dissolved solids and chloride salts.

A growing market for ZLD systems in the Oil & Gas industry is in places with limited infrastructure such as fracking well pads in the in oil-rich basins of Texas and Oklahoma in the USA. Increasingly, ZLD systems can be operated in remote areas or shale developments because many evaporation systems are modularized and even mobile today. They are designed, fabricated and delivered as a skid-mounted package that minimizes field installation work because all units are self-contained and need no connections within the package.

Oil refineries, liquefied natural gas plants, and other downstream facilities have a constant demand for water to produce outputs. However, they are often located in water-stressed areas. A global energy company developing a world-class gas-to-liquids conversion site in the Middle East engaged with Veolia to design and build the effluent treatment plant. In this process, wastewater will be treated by ultrafiltration and reverse osmosis to achieve high water recoveries for complete reuse within the plant. Thus, no liquid effluent will be discharged into the natural environment. Reverse osmosis brine treatment will be carried out by an evaporator that concentrates the brine followed by a crystallizer, a technology achieving zero liquid discharge where only salt crystals are produced for disposal.

A Proven Solution to Growing Challenges

Faced with mounting pressures from consumers growing aware of the impacts of production and its water consumption on the environment, industries are incorporating sustainability initiatives across their value chain. This is also true for water treatment systems. A zero liquid discharge approach uses technical innovation to close the loop, cut liquid waste and reuse clean water through highly efficient processes.

This helps to improve industrial productivity, protect ecosystems from harmful effluents and conserve water for the environment and communities. Many industrial plants in need of upgrading infrastructure have turned to ZLD to meet stricter local and state regulations.

Thanks to advanced brine management technologies that improve recoveries and reduce energy costs and wastewater disposal, ZLD is a solution that is up to the challenges posed by a future with rising water scarcity and growing demand for high-quality water.

Veolia provides industries with water treatment technologies, digital solutions, and lifecycle services that reconcile productivity and the protection of the ecosystem. With HPD® evaporation and crystallization, Veolia optimizes the use of local water resources through thermal separation processes that improve the sustainability and productivity of industrial operations.

> In broad terms, there are two general ZLD technologies that work to remove dissolved solids and impurities: thermal and membrane processes and frequently a combination of both in a hybrid form.

About the Author

***Matias Navarro** is a marketing specialist and market developer. With more than 10 years of international expertise working in the infrastructure, environment, and clean-tech sectors, he brings in-depth research focused on improving the competitive positioning, market strategy, and growth opportunities with Veolia Water Technologies.*

***Veolia Group** is the global leader in optimized resource management. With over 171,000 employees worldwide, the group designs and provides water, waste, and energy management solutions which contribute to the sustainable development of communities and industries. Through its three complementary business activities, Veolia helps to develop access to resources, preserve available resources, and to replenish them. In 2018, the Veolia group supplied 95 million people with drinking water and 63 million people with wastewater service, produced nearly 56 million megawatt hours of energy and converted 49 million metric tons of waste into new materials and energy. Veolia Environnement recorded consolidated revenue of €25.91 billion in 2018 (USD 30.6 billion).*

ZLD Solutions: Benefits for Various Industries

The recycle systems are combined with specialty water treatment chemical programs that substantially reduce water discharge (for example, cooling tower blow-down); and state-of-the-art effluent treatment plants are integrated with Zero Liquid Discharge (ZLD) processes.

By Ajay Popat

Total Water Management with Zero Liquid Discharge System for a Multinational Automobile Manufacturer

POLLUTION AND INCREASED demand have made good quality water-scarce and expensive, both in terms of the direct cost of water and the effect of unsuitable water on plant economics and product quality.

Meanwhile, disposal norms are getting tighter and their enforcement stricter.

Ion Exchange can help you to effectively and economically solve water scarcity problems by conserving vast volumes of water and protecting the environment by reducing discharge while generating substantial savings for you.

Ion Exchange's effluent recycle solutions are integrated to yield optimal benefits.

For instance, recycle systems are combined with specialty water treatment chemical programs that substantially reduce water discharge (for example, cooling tower blowdown); and state-of-the-art effluent treatment plants are integrated with Zero Liquid Discharge (ZLD) processes.

These are backed by comprehensive operation and maintenance services for high-performance continuity.

Industries that have installed our effluent treatment, recycle and ZLD systems have gained an excellent payback on their investment through:

- Assured availability of water for process needs as well as low end uses.
- Less requirement of freshwater. Therefore, considerable savings in freshwater costs.
- Additional savings through the recovery of valuable by-products for reuse in the process.
- Compliance with pollution control regulations and a clean environment through reduced/ zero effluent discharge.

Our ZLD system benefits accrued by some of our customers:

- A refinery at Jamnagar (Gujarat, India) installed a water treatment plant that is designed to contain and treat all internal process/ utility wastewater and storm/fire water, with the objective of zero liquid discharge.
- A leading fertilizer company in North India has installed a recycling plant - design capacity 128 m^3/h. Cooling tower blow-down and regenerate waste from the demineralization plant are recycled and reused in the process.
- An internationally renowned automotive manufacturing company has commissioned Ion Exchange to set-up an integrated water and wastewater treatment and ZLD facility to manage waste generated in its manufacturing process and township.
- A leading integrated steel manufacturer has implemented a series of near ZLD projects with the objective of reducing water conservation per tonne of steel produced to enhance their competitiveness through reduced water footprint.

About the Author

Ajay Popat *is the President of Ion Exchange (India) Ltd. He is responsible for technology, corporate marketing, corporate diversification and communication.*

Mr. Popat pursued his engineering degree in Plastics Technology from the Plastic & Rubber Institute, UK and Masters in Business Administration specializing in Marketing & Strategy with honors from NMIMS Institute. He has also been conferred with a Fellowship by Indian Plastics Institute in 2007.

Associated with Ion Exchange since 1994, he has spearheaded several initiatives in developing and successfully commercializing proprietary, advanced & sustainable technologies for purification & separation in water and wastewater treatment. During his tenure, he successfully conceived the idea of a separate Environment Management business, which he formed through a joint venture between Ion Exchange and a leading Belgium company. Under his leadership as a CEO of this joint venture (and then elevated to the Board of the Company), Mr. Popat created a leadership position for the joint venture, leading to his elevation as the President of the parent company, Ion Exchange (India) Ltd.

Ion Exchange (India) Ltd *offers total water and environment management solutions for all sectors - infrastructure, industry, institutions, municipal, homes & communities, urban, and rural. Its 360° environment management adds value across the entire circuit - from influent water through potable and industrial process water to effluent/sewage treatment and water recycle for zero discharge and waste to energy projects for solid waste management.*

Ion Exchange is a manufacturer of world-class ion exchange resins for water and non-water applications, membranes, water treatment chemicals, and speciality process chemicals, in ISO 9001, 14001 and OHSAS 18001 certified facilities. The company offers design and supply of water, process liquid, wastewater treatment, water recycle plants - packaged, pre-engineered and custom-built, on turnkey, BOT and EPC basis.

Resource Recovery from Pharmaceutical Industrial Effluents Using an Improved Membrane Distillation (IMD) System TS-30™

Pharmaceutical industries indiscriminately generate a huge volume of liquid waste. In general, these liquid wastes are generated during the manufacturing of pharmaceuticals. Effective treatment of liquid waste from the pharmaceutical industry is one of the key challenges due to its complexity and hazardous nature.

By Dr. J Antony Prince and Eddy Siswanto

Figure 1: The Highly Hydrophobic Hollow Fibre Membrane STOMATE®

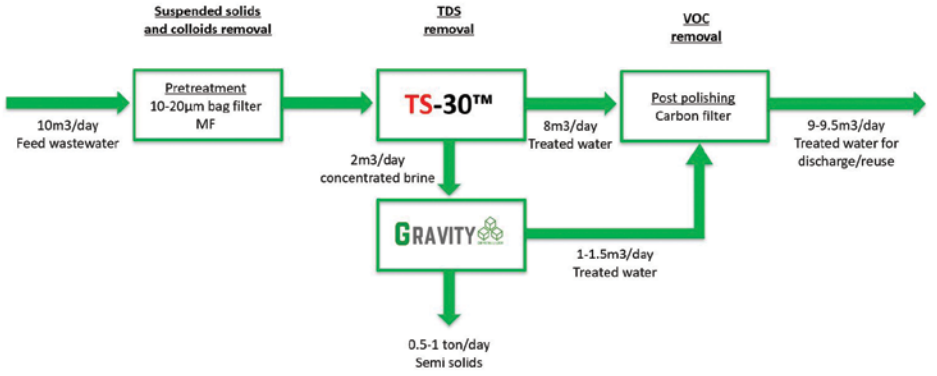


Figure 3: The Novel Methods for Metal Finishing Industrial Effluent Treatment with Zero Liquid Discharge (ZLD).

PHARMACEUTICAL INDUSTRIES INDISCRIMINATELY generate a huge volume of liquid waste. In general, these liquid wastes are generated during the manufacturing of pharmaceuticals. Effective treatment of liquid waste from the pharmaceutical industry is one of the key challenges due to its complexity and hazardous nature.

Typically, pharmaceutical industrial effluents contain drug residues and cleaning agents (from CIPs, Clean In Place) with high Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), pharmaceutically active compounds such as hormones, toxic substances, antibiotics (PhACs) and Volatile Organic Compounds (VOCs) that constitute a potential threat to the entire ecosystem.

The continuous accumulation of these compounds poses a serious threat to human health. The highly variable nature and composition of the raw materials affect the composition of liquid waste as well. This variation in liquid waste composition is one of the key challenges encountered in handling liquid waste from the pharmaceutical industry.

Traditionally, physico-chemical methods such as neutralization, adsorption, ion-exchange, coagulation-flocculation, precipitation, electrochemical process, chemical reduction, etc., were used to treat the pharmaceutical industrial liquid waste effluent.

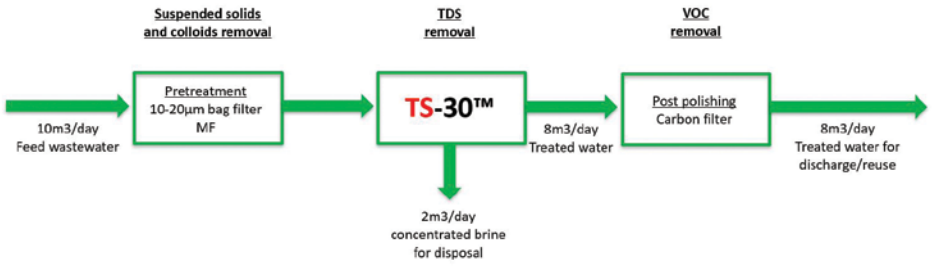


Figure 2: The Novel Methods for Metal Finishing Industrial Effluent Treatment with Minimum Liquid Discharge (MLD).

In many cases, the combination of the above process was used to achieve better efficiency. However, these physical and chemical treatment processes are unable to meet the requirements due to their poor efficiency in removing TDS and dissolved COD.

Other methods such as Advanced Oxidation Process (AOP), electro-coagulation, biological treatments, aerobic & anaerobic digestion, activated sludge, and allied process were also used to treat pharmaceutical industrial liquid waste effluent. These processes were good to remove certain contaminants but not able to remove the TDS from the effluent completely to meet the liquid discharge quality.

Pressure driven membrane processes like Microfiltration (MF), Ultrafiltration (UF) and Nanofiltration (NF) were used as post processes for the physico-chemical treatment methods to achieve the desired quality for discharge.

UF and NF methods can handle the low molecular organics and residues of the drug compounds but not the TDS and dissolved COD. Reverse Osmosis (RO) is well known for the removal of TDS from the pharmaceutical industrial effluent.

However, the RO process could concentrate the waste only to a certain percentage (up to 7% TDS) due to high osmatic strength in the concentration (discharging the RO brine is another big challenge). In many cases, the effluent contains 5-10% salt (TDS) where it is not possible to deploy the RO process.

Use of Zero Liquid Discharge (ZLD) systems could solve the problem. However, most of the ZLD systems use conventional distillation, evaporation and crystallization methods. These conventional distillation units are complex in nature, it occupies more space, consume more energy and requires high capital investment (especially for smaller capacity - 1 to 100 m^3/day where the capital cost of the conventional thermal systems is around 50k USD to 10k USD/m^3).

As most of the pharma companies producing liquid waste with a volume of <50 m^3/day, they need to pay a very high capital cost. Thus, the companies prefer to send the liquid waste for disposal and pay from 20$/ton to 450$/ton as disposal cost.

Hence, inexpensive, compact and environmentally friendly technologies are critical for brine treatment and Zero Liquid Discharge (ZLD)

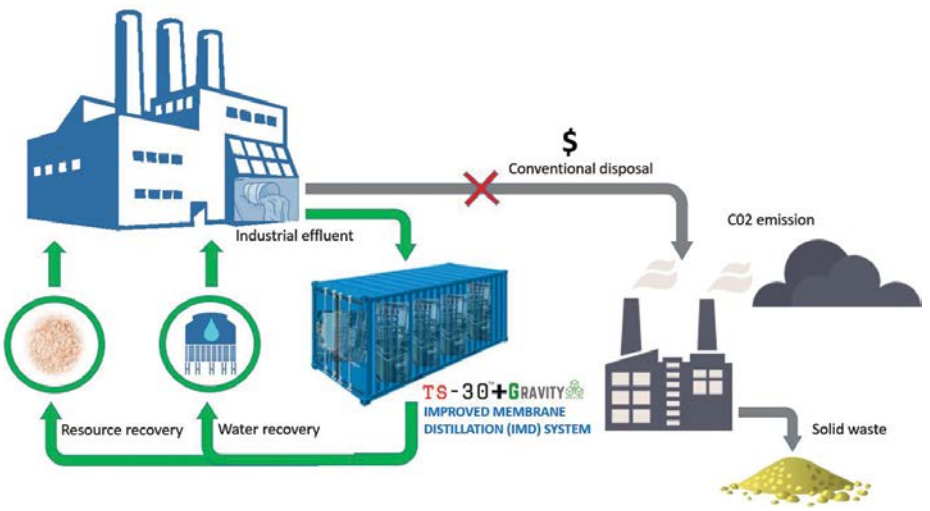


Figure 4: The Concept of Circular Economy in Pharmaceutical Industrial Effluent Treatment

applications for the pharmaceutical industry.

Membrane Distillation (MD) is a thermal membrane process that is being considered worldwide as a low cost, energy-saving alternative to conventional separation processes such as distillation and evaporation.

In MD, a membrane permeable to vapor but impermeable to liquid water separates a heated feed water stream from the product stream. Water vapor from the heated stream passes through the membrane due to the gradient in the vapor pressure and condenses in the product stream. MD is a good option to treat the wastewater containing inorganic contents. However, the current MD membrane has limitation to treat industrial wastewater containing high organic content.

The membranes are very sensitive to acid and organic solvents that will alter the membrane surface leading to membrane wetting. If the membrane undergoes wetting, it will allow the contaminant to pass through the membrane and hence this process has limitation in operating to treat pharmaceutical industrial effluent.

Several methods have been explored to prevent membrane wetting. The current solution to wetting is to apply a finely porous hydrophobic coating, which helps to increase the hydrophobicity while maintaining acceptable porosity. However, it reduces the pore size of the membrane, which in turn reduces the performance.

Another method to increase the hydrophobicity is by introducing fluoride-containing polymers or additives into the dope solution.

Memsift Innovations Pte Ltd has developed a unique highly hydrophobic hollow fibre membrane STOMATE® for MD application using proprietary material that contains 10X higher fluorine atoms per unit compared to current material. It can overcome the wetting issue in MD.

In addition, Memsift also has an Improved Membrane Distillation (IMD) process TS-30™ that utilizes the temperature difference and the pressure difference across the membrane as a driving force. The system works on the principle of expansion-evaporation and the STOMATE® functions as the porous plug or the expansion valve in the system.

This process helps to increase the mass transfer due to heat loss and helps to recover the heat, which improves the thermal efficiency of the entire system. The system operates at relatively low temperature and pressure compared with the conventional evaporation and other thermal-based separation processes.

Memsift Innovations Pte Ltd has developed a unique highly hydrophobic hollow fibre membrane STOMATE® for MD application.

Memsift has also developed a new generation crystallizer GRAVITY™ that works in the principle of centrifugal force and gravitational force with some temperature difference. The newly developed crystallizer requires one-third of the energy that is being used for the conventional crystallizers.

The IMD system can be operated with minimum pre-treatment for the pharmaceutical industry and the crystallizer can be used as a post-treatment to the IMD system to recover more water that makes the whole system to Zero Liquid Discharge (ZLD). By doing so, we would be able to recover resources like metal salts and catalyst.

Figure 2 & 3 show the novel methods for pharmaceutical industrial liquid waste effluent treatment with Minimum Liquid Discharge (MLD) and Zero Liquid Discharge (ZLD).

Recently, four different case studies were carried out for a pharmaceutical company in Singapore. The effluents were collected from various

Water Quality Parameter	Sewer Discharge Limit	Permeate Quality
Total Dissolved Solid (TDS)	3000 ppm	<300 ppm
Total Suspended Solid (TSS)	400 ppm	<2 ppm
Chemical Oxygen Demand (COD)	600 ppm	<100 ppm
Chloride (as Chloride Ion)	1000 ppm	<100 ppm
Sulphate (SO4)	1000 ppm	<100 ppm
pH	6-9	7.6±0.2
Grease and Oil	60 ppm	<2 ppm

Table 1: Product Quality and the Discharge Limit

Figure 5: Pilot Scale TS-30™ IMD System

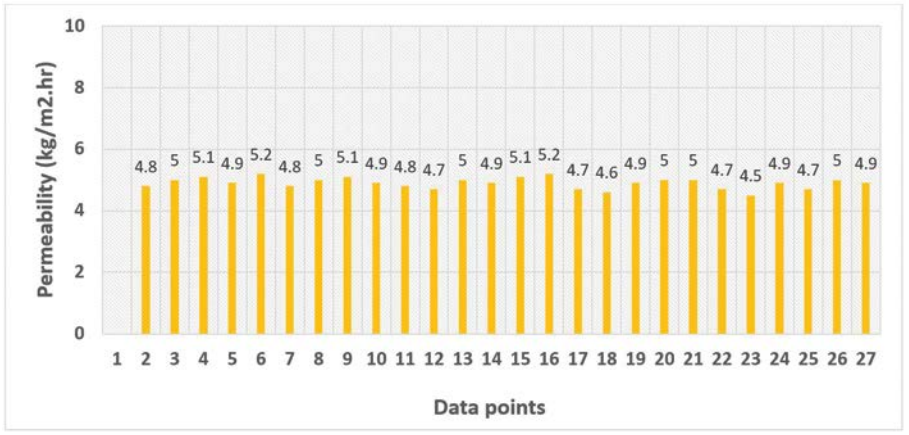


Figure 6: Permeate Flux vs Time

processes such as chemical synthesis/ production and cleaning. Three case studies were carried out without crystallizer as per the process described in Figure 2 and one case study was with our newly developed GRAVITY crystallizer as per the process described in Figure 3 and here, we would like to discuss this further.

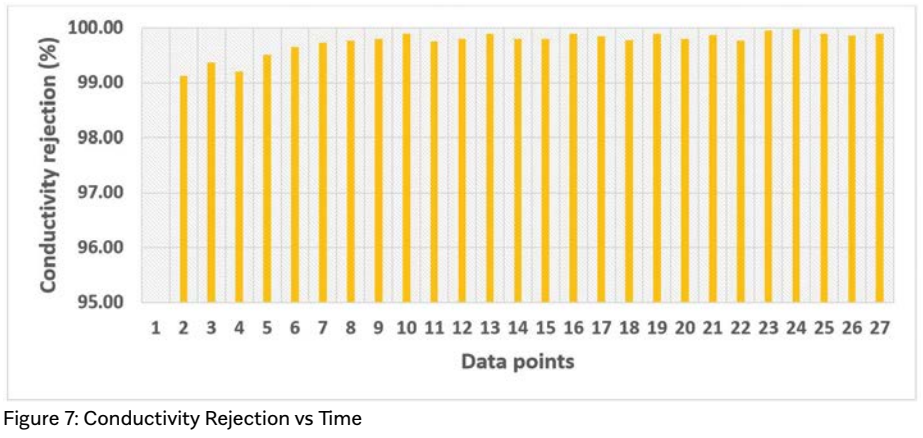


Figure 7: Conductivity Rejection vs Time


Figure 8: Image of Feed and Product Water

The outcomes confirmed the high possibility of resource recovery or circular economy in pharmaceutical industrial effluent treatment. Figure 4 shows the concept of a circular economy in pharmaceutical industrial effluent treatment and Figure 5 shows the actual image of a TS-30™ IMD system.

The feed water was heated up with an electrical boiler to 70±3 °C and supplied to the feed inlet of the membrane module by a circulation pump with a velocity of 0.42 m/s. A vacuum pressure of -0.2 bar was applied in the expansion chamber/ permeate side. The vapor was collected and condensed in the condensation chamber by using cooling water (temperature 30±3 °C).

The condensed permeate was collected in the permeate tank and the volume was measured to calculate the permeate flux. The concentrated brine from the TS-30™ system was pumped to the GRAVITY crystallizer where the saturated crystals were separated by centrifugal force and gravity force with minimum temperature difference and the supernatant was passed back to the TS-30™ IMD system.

Feed, permeate and the concentrated effluent samples were collected to analyze the water quality and the separation efficiency of the system. The following table shows the product quality and the discharge limit.

From the analytical data it was found that the TS-30™ IMD system together with the GRAVITY crystallizer can helps to recover >95% of the water from the pharmaceutical industrial effluent and the treated water meets the discharge limit without further post polishing.

The treated water can be reused with minimum post polishing. The permeate flux and the conductivity (rejection) were stable throughout the experiment. Figure 6 & 7 shows the permeate flux and conductivity rejection vs time. Figure 8 shows the images of feed and permeate.

Figure 9 shows the recovered ammonium sulphate salt. The recovered ammonium sulphate can be used as fertilizer or can be sold as a 2nd quality product that creates a new revenue stream.


Figure 9: Concentrated/ Recovered Ammonium Sulphate Salt

Recently, four different case studies were carried out for a pharmaceutical company in Singapore. The effluents were collected from various processes such as chemical synthesis/ production and cleaning. Three case studies were carried out without crystallizer as per the process described in Figure 2 and one case study was with our newly developed GRAVITY crystallizer as per the process described in Figure 3 and here, we would like to discuss this further.

About the Authors

Dr. J Antony Prince *is the Founder and Chairman of Memsift Innovations Pte Ltd.* ***Eddy Siswanto*** *is the Director and Principal Engineer at Antero Engineering Pte Ltd.*

The Dark Side of Zero Liquid Discharge (ZLD) Treatment

Pruthviraj Parmar is a young and dynamic student pursuing a Master degree in Water, Wastewater and Waste Engineering at University of New South Wales, Australia. He has completed Bachelor and Master of Science in Environmental Science, from The Maharaja Sayajirao University of Baroda. He is working in a local government sector with a solid waste management team and leading a project of Integrated Waste Management in Randwick City Council. **Mayur Sharma** interacted with him about the theme of this cover story - ZLD.

Q. How does a primary ZLD plant work?

Mr. Parmar: ZLD treatment is a combination of several methods such as evaporation, reverse-osmosis, crystallization, heating-cooling, and other upgrading methods depending upon the type of industry dealing with. Before going for the above treatment, wastewater is pre-treated by process of ultrafiltration. As the system is costly pre-sorting and higher particle removal is mandatory. In the process of evaporation, all water is converted to vapor pressure, which can produce heat for cooling water towers in the industry while the solid move forward for crystallization. Simultaneously, solid cakes generation take place. This solid cake contributes to landfill.

Q. Tell us about the cost aspect of ZLD plant.

Mr. Parmar: ZLD process is one of the costliest methods for treating wastewater that can reach up to 100 million dollars in investment and running the plant, which is 2-3 times the cost of biological wastewater treatment. Hence, developed countries are usually the sole users of this treatment.

Q. ZLD plant: What are the benefits vs. burden?

Mr. Parmar: Here are the benefits: ZLD produces brine solutions, highly concentrated salt, which is a benefit from a system. Moreover, it produces reusable water for industry. Moreover, in a water-scarce region, ZLD can be very useful. It is useful in following guidelines for releasing wastewater in an ocean or marine environment.

The burdens are: ZLD system generates concentrated waste in the form of solid cakes which goes to a landfill site after dewatering. This hazardous waste contains high cations and anions concentration. This toxic compounds called as trade waste are highly contaminated and brings high risk in dealing with such type of waste. Moreover, hazardous waste generated from ZLD could be 5-10 times more concentrated than solid waste generated from a biological wastewater treatment plant. Another major issue of concern with ZLD is energy consumption, which is very high in comparison to a biological wastewater treatment plant.

Q. What is the environmental risk in regards to waste generated from ZLD wastewater treatment plant?

Mr. Parmar: The workers working with such waste should always wear PPEs. Moreover, this waste can be an environmental risk if not properly collected, stored, transported, and disposal. Advancement in technology, specially ZLD, does not only mean that we are reducing waste but on the other side, it increases environmental risk. The cost of ZLD can be very high, and expertise is required to run the plant. However, the failure of a plant can lead to investing millions of dollars.

Q. What is the LCA of ZLD plant?

Mr. Parmar: High usage of chemicals, RO filters, and evaporators increase energy utilization and high transportation leads to increase in GWP, generation of Oxides of Nitrogen (NOx) and CO^2 increases the overall Global warming potential and CO^2 of a plant in comparison to biological wastewater treatment plant. A ZLD plant is expected to produce an average of 5 kg. CO^2 eq. GWP. LCA and LCIA suggest that biological wastewater treatment plant produce less burden on the environment than the zero liquid discharge treatment plant.

Q. What are the types of waste generated by ZLD plant?

Mr. Parmar: The hazardous waste generated from the ZLD plant is untreated before final disposal in a landfill, which can be a considerable concern and significant environmental risk. However, the design of a landfill also plays a significant role in regards to their disposal and environmental contamination risk.

There is no other option available for solid waste generated from ZLD plant except for landfill.

Q. Interlinking waste from wastewater and solid waste for a sustainable future?

Mr. Parmar: As known, the environment is an interlinked system. Impact on one component of the environment can cause changes in the whole ecological system. With increasing awareness of the complex environmental system, it is essential to study the post effect of waste disposal. Changing the source of waste or state of waste is not a viable option. Increase in hazardous waste with high environmental risk quantity and finally disposing it into a landfill or deep ocean is an environmental hazard and can lead to environmental contamination in the upcoming future.

Q. Is ZLD better for future environmental in regards to environmental risk and land contamination?

Mr. Parmar: This dumping of solid cakes can be a significant concern for the upcoming future. The possible worse environmental risk that could occur is "Rewriting Minamata case of Japan," but without highlighting any particular chemical. The future research should focus on effective treatment of solid cakes generated from ZLD and how to improve disposal techniques.

Leachate formation, groundwater contamination, land contamination, water contamination, aquatic habitat imbalance, aquatic and marine water quality-related issues, and toxic gas production are some of the possible this that can occur due to illegal or improper dumping of solid cakes generated from ZLD plant. All these issues are directly or indirectly related to disposal technique and disposal location of the solid waste generated from the ZLD plant.

ZLD is beneficial for water scare countries like China and other western countries where available water is low, highly contaminated water is already present. However, continual improvement and upgradation of ZLD are also necessary for a better environment. "Low waste and high-risk is not a good option in comparison to high waste and low-risk." However, to change this scenario, high funded research and investigation should be carried out, leading towards the betterment of the ecological system focused on ZLD waste management.

Upgrading ongoing industrial wastewater treatment plant in comparison to implementing ZLD plant can be a viable option. This option is cost-effective (cheaper), secure in comparison to ZLD upgradation, produce waste with lower toxicity and lower environmental risk.

The Smart Alternative to Disposal

When processing 2,000 m³ industrial wastewater in-house instead of disposing of the water with waste management companies one can save in ten years more than €1,000,000.00. These savings justify investment in water processing equipment in almost every case.

By Jochen Freund

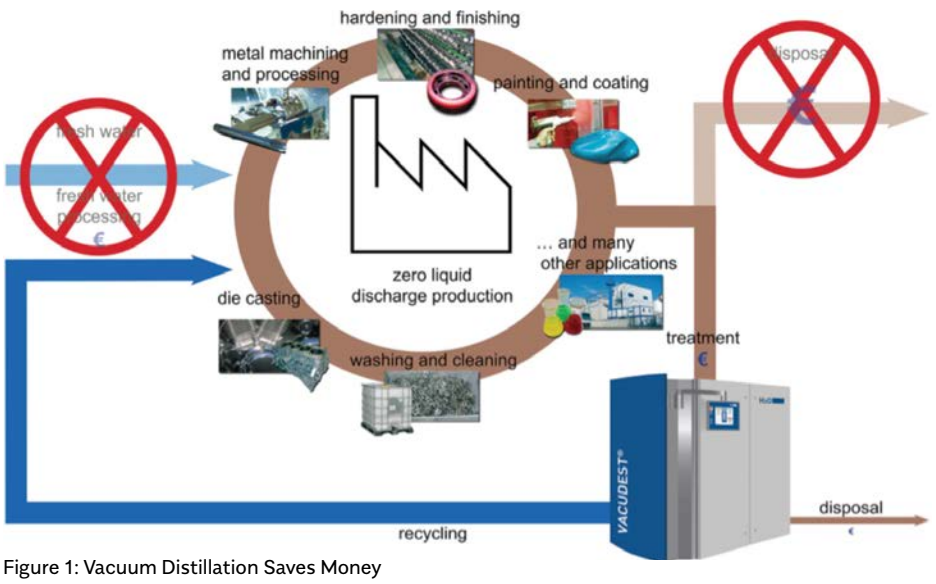


Figure 1: Vacuum Distillation Saves Money

Chemical-Physical Treatment
In chemical-physical treatment pants several chemical substances are added to the process water in suitable order, resulting in precipitation of contaminants. The solids are filtered and disposed of with waste management companies. As an alternative or as additional treatment ion-exchanger columns are used to separate the contaminants. The treated water can be disposed of into the public sewer system in most cases.

Process Water Recycling Secures Tomorrow's Earnings

Do you have wastewater in your production which cannot be disposed of into the public sewer system? How do you manage this wastewater? Often this wastewater is disposed of with specialized waste management companies. This is a straightforward procedure not disturbing the day to day business in the production. However; here big saving possibilities are hidden.

When processing this water in-house 70% of the occurring cost can be saved. When processing 2,000 m³ industrial wastewater in-house instead of disposing of the water with waste management companies one can save in ten years more than €1,000,000.00. These savings justify investment in water processing equipment in almost every case.

But Which Process for the Treatment of the Wastewater is the Right One?

On the market several different technologies are available, all of them offering pros and cons. The variety of possibilities makes the proper selection of the right process difficult.

Which Processes are Available?

The most common processes for the treatment of industrial wastewater are chemical-physical treatment plants, membrane plants, and vacuum distillation systems.

Which is the Right Process?

In some cases, there is only one processing possibility. It can be determined by the amount of wastewater and degree of pollution. If mostly inorganic pollution membrane filtration plants can be excluded since processing would be too costly.

If the water contains latex, paint or proteins vacuum distillation is not applicable. Figure 2 shows that there is an extensive area where all three processes are an option. In this area, the different processes have to be compared carefully.

Which are the Important Criteria to Select the Process?

First of all the general requirements have to be fixed. The most important criterion is the quality requirement for the treated water. This criterion is the basis for analysis of all of the following criteria.

Certainly, the most important criteria are costs. Not only investment but also operation costs have to be considered. What sense does a low investment make, if high operation costs are eating up this advantage within shortly?

Process flexibility is a very important factor as well. How does the processing plant react if wastewater quality varies or even changes composition totally within shortly? What happens if alternative process chemicals are applied in the production process?

Finally, reliability has to be looked at. How complicated is the operation of the system? In how far can the operators themselves react in case of malfunction?

Zero Liquid Discharge: Is it Feasible?

Nowadays many companies focus on sustainability to save valuable resources. Self-imposed environmental standards are often higher than required by the respective authorities. This certainly includes responsibly dealing with the valuable freshwater resources. If the aim is zero liquid discharge production facilities and/or if very pure rinsing waters are required, vacuum distillation is the best choice. Distillate quality is high enough to allow recycling without or with simple post-treatment only. The distillate is normally almost free of oil and heavy metals.

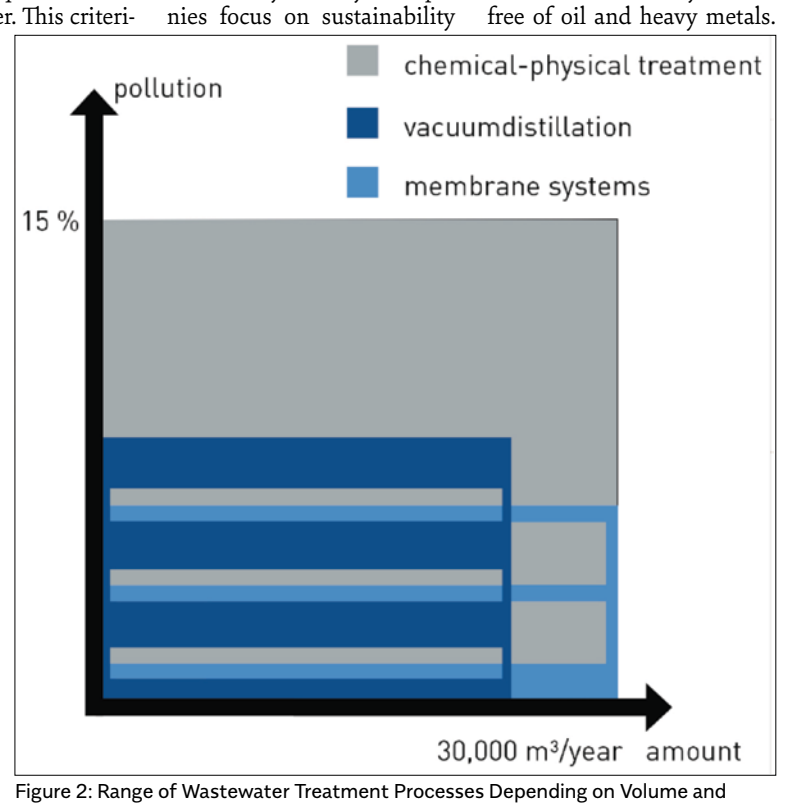


Figure 2: Range of Wastewater Treatment Processes Depending on Volume and Grade of Pollution

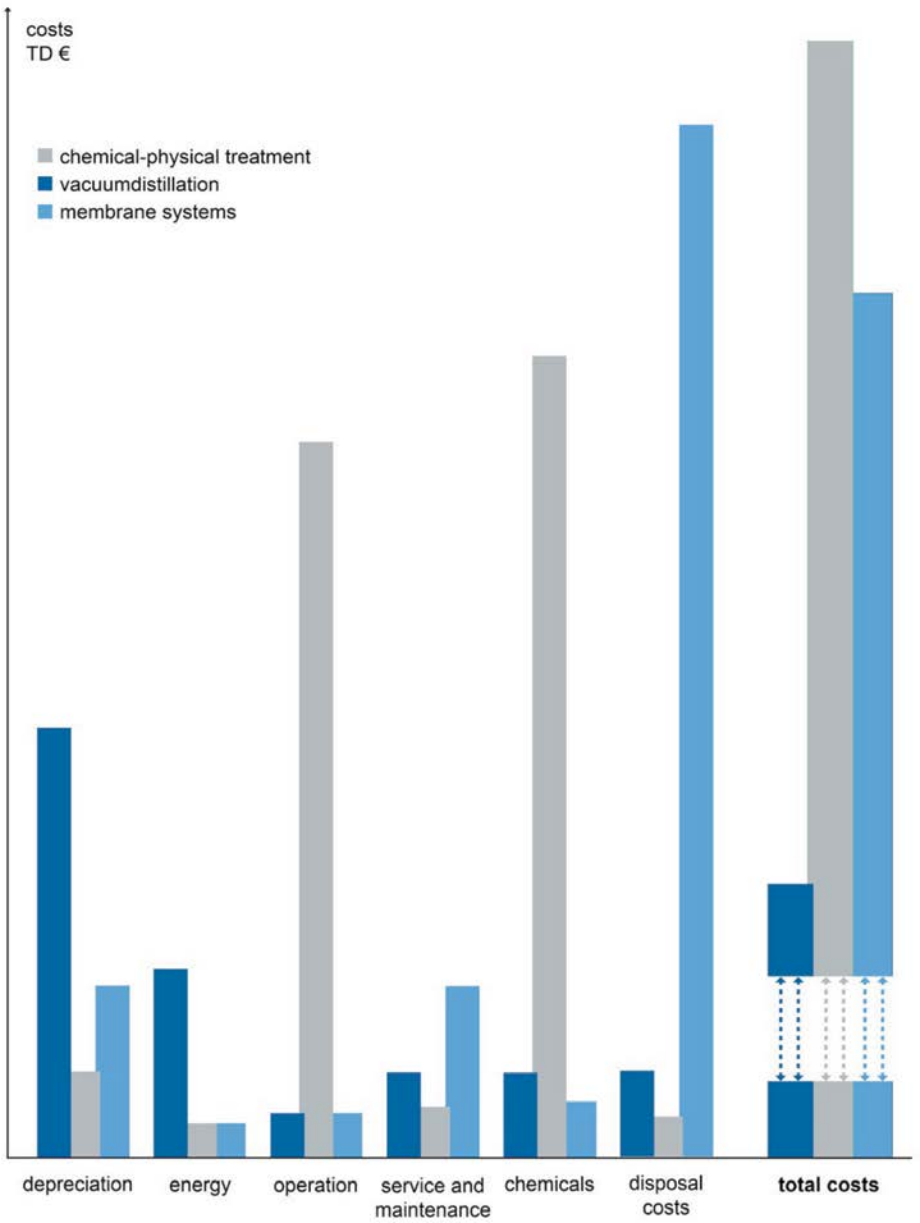


Figure 3: Comparison of Operation Costs for Process Water Treatment Systems

Only if quality requirements to rinsing water are very high post-treatment with ion exchangers is necessary.

When using other processes like chemical-physical treatment or membrane filtration the quality of the treated water is below freshwater quality. Thus it is more feasible to dispose of the treated water into the public sewer system and process freshwater to the required quality for the production process.

When investigating investment and operating costs of vacuum distillation systems in the area of 100 to 30,000 m^3 wastewater per year with a pollution degree lower 8% one can see the feasibility advantages of vacuum distillation technology. Investment costs are higher compared to other processes, however, operation costs are unbeatable. Chemical-physical treatment has very high chemical consumption figures and operation is time-consuming and demanding, especially if the wastewater composition is complex. Consumption figures of membrane filtration plants are moderate, however, retentate amount is rather high leading to high disposal cost. Figure 3 shows that higher investment costs of vacuum distillation systems are compensated quickly by lower operation cost.

In terms of flexibility and reliability vacuum distillation systems are setting benchmarks. Modern systems adapt to varying process water compositions automatically. If for instance designed for the processing of spent coolant emulsions small and simple modifications allow processing of galvanic rinsing water instead. Smart maintenance concepts and intelligent process visualizations improve system availability and ease operation. In so far modern vacuum distillation systems as reliable as the specialized

Membrane Filtration
In membrane plants the wastewater is filtered through water-permeable membranes. The contaminants are retained and disposed of in liquid form with waste management companies. The permeate can be disposed of into the public sewer system in most cases.

Figure 2 explains process selection depending on wastewater volume and degree of pollution. In the area where several processes are possible, vacuum distillation proves to be the most feasible and environment-friendly process. In other areas, it is recommendable to think about a combination of several processes (for example membrane filtration plus vacuum distillation for the processing of retentate.

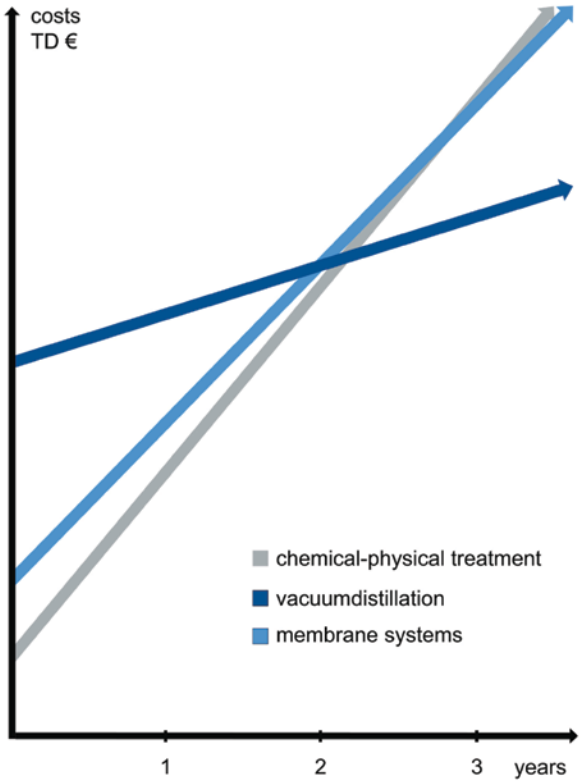


Figure 4: Comparison of Life Cycle Costs of Process Water Treatment Systems

Vacuum Distillation
In vacuum distillation systems the contaminated process water is evaporated under vacuum. The caloric energy of the emerging steam is used to heat up and evaporate the feed water, thus the systems are very energy efficient. The distillate can be recycled back into the process, creating a zero liquid discharge production. The evaporation residue is disposed of with waste management companies.

About the Author

Jochen Freund *is Head of Sales at H2O GmbH.*

H2O GmbH *is a leading waste management company picking up the wastewater frequently.*

producer of vacuum distillation systems for industrial wastewater management for the metal processing industry, automotive industry, aviation industry, machine-building industry and many other industrial sectors.

Distribution Systems for Limited Quantity Domestic Water Supply in Indian Socio-Economic Environments

The drinking water distribution to the households in Indian cities provided by the municipalities and corporations at present mostly are not reliable for Demands Driven Approach (DDA) and the most of the households arranged their own independent alternate water sources in addition to the municipal water supply to meet their daily water needs.

By Rajeshwar Rao Bandari and Shiva Ram Bandari

This Image is for Representation Purpose Only. Photo Credit: Pixabay.

Introduction

In general, as per the planning of several developed countries' practices, for safe drinking (domestic) water supply, Distribution Systems (DNS) are continuous (24x7) systems. The water is pumped continuously (24x7) to a distribution pipe network with average hour demand discharges and then reaches up to top-floor consumers through directly connected internal in-house plumbing for instant use with adequate minimum residual pressures heads around 30m and during lesser demand periods (in nights) the pumped surplus water causes to rise the system pressure then the surplus water is moved to an elevated storage tank (floating on DNS) and thus water balancing takes place from both the ways to meet the peak hour demands (1.5 to 2 times) without a drop in required minimum residual heads around 30m. As the water withdrawals distributed based on demands dependent, the pipe sizes provisioned for the peak hour

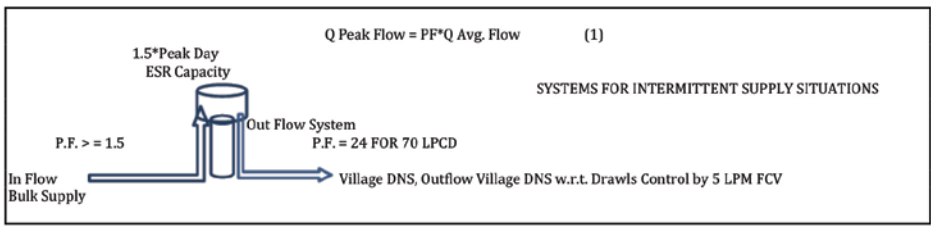


Figure 1: A Village System Feed with Bulk Water Supply

demands with peak factor of 1.5 to 2 in several Developed Countries practice with higher per-capita demands.

The drinking water distribution to the households in Indian cities provided by the municipalities and corporations at present mostly are not reliable for Demands Driven Approach (DDA) and most of the households arranged their own independent alternate water sources in addition to the municipal water supply to meet their daily water needs. The actual utilization of the distribution systems, based on the piped water supply hydraulics the water withdrawals by the consumers' end are open flows by the yard connections in the premises of the households and the pressure available at the nodes exhausts fully to the atmospheric and higher outflows accordingly. Thus, water withdrawals with concentrated demands as the extent of pressure-dependent outflows for collection of water to fulfill the storage in short durations at all the household level. And thus the demands are not distributed as envisaged in DDA.

As the piped water supply systems planned for continuous supply (24x7) for peak demands with peak factor between 2 to 3 only as envisaged in CPHEEO manual assuming the demands (water withdrawals) distributed as in DDA. As the existing method for piping systems, the pipeline sizes are the lesser capacity to sustain the minimum pressures at higher water rate of withdrawals to fulfill the storage purpose of all the households at peaks and thus the pipe mains sizes not sufficiently for the pressure-dependent outflows. And the pipeline operators in municipalities, closes the water supply to all at the beginning and starts the supply only after filling the Elevated Service Reservoir (ESR) and releases the supply for the streets by one after the other in short durations for each street. Accordingly, intermittent supply takes place in streets alternately for short durations instead as planned continuously for 24x7 as envisaged in CPHEEO manual.

The distribution systems functioning (operations) in India are not for continuous supply (24x7) and thus not similar to the practice in developed countries as envisaged in planning and design patterns. Accordingly, there is a change in the pattern for the drinking water supply systems in India, in general, the water is collected to an Elevated Service Reservoir (water tank) directly by available clear water provision of pumping/gravity from bulk water supply and then the stored water is distributed under little initial pressure

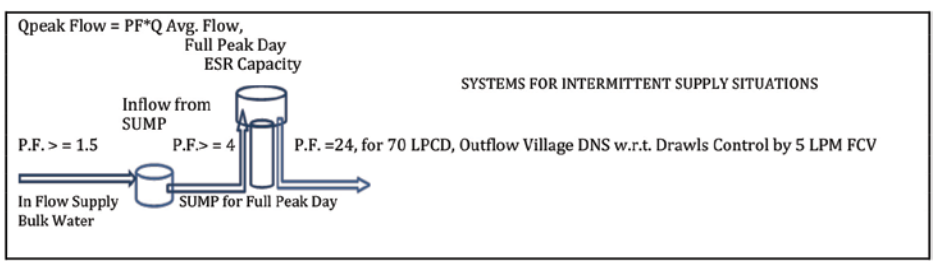


Figure 2: A Village System Feed with Bulk Water Supply with Isolated Sump.
Note 1: ESR Storage Tanks with One Full Peak Day Demands in Additions to One Full Peak Day Sump.
Note 2: Pipe Lines to be Designed for Individual Peak Factors as Mentioned.
Note 3: For Individual (Water Treatment Plant) WTP, Big Villages in Place of Sump Replaced by WTP.

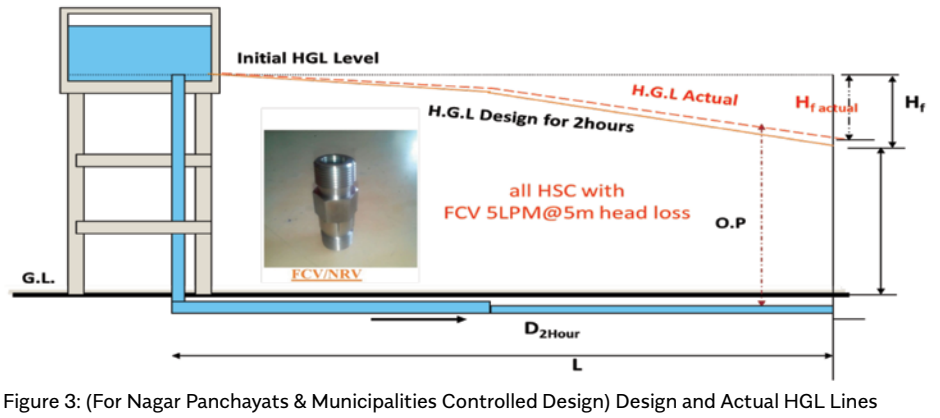


Figure 3: (For Nagar Panchayats & Municipalities Controlled Design) Design and Actual HGL Lines Matches for the New Methods for Restricted Drawls With Respect to Pipe Sizes Designed for 2 Hours of Supply Rates for Maintaining Minimum Pressures to All HH Simultaneously Drawls.

head (of around 15m at ESR) through gravitational pressure flow from the tank to the consumers by way of operating the branch valves between the streets alternately one after the other in short durations with lower pressures than minimum prescribed which leads improper distribution within the streets.

The consumers are not systematic in the use of safe water. At present their minds get disturbed with the existing unreliable water supply systems so that they eagerly await for water and try to collect the full day's demands in short durations at once for the storage in their houses - instead of directly using it for instant needs, as envisaged in DDA. The planning of safe drinking water supply systems at lesser costs may not fulfill the goals in reality with the present unfeasible socio-economic environments as the systems are functioning with very less reliability. The systems with insufficient provisions may lead to purpose of habitants failing and the systems running with less reliability.

This article describes a new approach for the design of all components of the distribution system suitable to Indian cities and villages for desired (for limited per-capita supply) quantity supply even in peak hours on a reliable basis to tackle the pressure problems in intermittent supply situations. In this, the system provisions are based on the limited rate of withdrawals restrictions around 5 LPM flow rates at each consumer connections, even metering provisioned with control water tariffs. And accordingly, the DNS redesigned/ rearranged the pipe sizes with respect to the cumulative discharges through simultaneous water withdrawals at the consumer ends is equivalent to 5 LPM flow rates at each households service connections.

The new method of the distribution system is scalable to operate for future higher per-capita service levels by simply increasing the supply hours without changing the pipelines.

As per norms of the Indian Governments, under the NRDWP, safe and adequate water is to be provided readily and conveniently, accessible by users at all times (i.e. during all seasons round the clock) and in all situations (at the peak demand requirements i.e. occasions of festival days/ Sundays). So, there are many constraints involving the hurdle in continuous water supply, in the present Indian socio-economical environment conditions.

The Main Issues of Unreliability of Distribution Systems

The distribution systems provisioned in CPHEEO manual may only suitable for maintaining the minimum terminal pressures at all consumer points for the systems running based on demands dependent only, flow drives in-times as demands arise for needs only otherwise no/less flow run in main lines during midnights, and:

- Adoptable for the systems if it runs with continuous water supply on continuous distributed demands around the clock for instant use when for water needs.
- The rate of water withdrawals by the consumers to be within the carrying capacities of pipe mains, limited to the assumed peak hourly demands as pipe sizes designed for it for maintaining the minimum residual pressures at all points under peak flow running conditions.
- No water withdraws for household's storage purpose and water withdrawals only for instant-use when water needs as and when demands arises and not at all the water withdrawals to exhaust the entire pressures at consumer points as in pressure-dependent outflows.
- Only suitable for peak hourly consumptions within the peak factor of 2 to 3 (as per CPHEEO manual) over average hourly discharges distributed around the clock and fails to maintain the minimum pressure in the pipe mains for more than peak demands driven by the pressure-dependent withdrawals and leads to

intermittent supply situations.

- The distribution systems functioning (utilization) in India are not at all for continuous supply and thus not similar to the developed countries practices as envisaged in planning and design.
- The consumers at present are not systematic in the use of safe water. Their minds are disturbed with the existing unreliable water supply systems and thus they eagerly await for water and try to collect the full day's water quantity at once in short durations for storage of water in their houses instead of directly using it for instant needs (distributed demands) as envisaged.
- In lines of continuous water drawls systems by 24x7, as envisaged to run with less peak design demands (peak factor 2 to 3), the pipe networks cost seems to be a little less with the undersized pipe mains against the requirements in India.
- The planning of safe drinking water supply systems at lesser costs criteria may not fulfill the goals in reality with the present unfeasible socio-economic environments as they are at the initial stage to change, and reforms for upgradations in the efficient use with good water management practices by the stakeholders may be expected in the future.
- The systems with insufficient provisions lead to fail the purpose of habitants and the systems run with less reliability and the up-gradation process continues forever with negative results.

Need for a new approach for optimum design of all components of the distribution system suitable to Indian cities and villages for desired (with limited per-capita demands) quantity supply even in peak hours on a reliable basis to tackle the pressure problems in intermittent supply situations.

New Approach for Optimum Design of Distribution Systems

To solve the problems in intermittent supply situations, presently, the supplied water quantity from the Elevated Service Reservoirs, distributed equally to all households is a primary need.

- For this, one aspect is to control the rate of drawls at consumer connections to tackle the excess withdrawals due to pressure-dependent outflows for intermittent supply situations. This can be achieved by fixing unique tampered proof flow control valves of 5 LPM drawls for all households' service connections in place of the ferrule. Many experiments conducted in several villages under mission Bhagiratha Project in Telangana State for acceptance of households withdrawals restricted to 5 LPM @ 0.5 bar pressure for the ½ " service connections as minimum accepted limit and now fixing household FCV is as mandatory for consumer connections. No higher sizes for domestic connections and all old connections to be replaced with 5Lpm FCV at first instance to avoid social disorders.
- The second aspect is for maintaining the minimum residual pressure heads at all points. Accordingly, the DNS redesigned/ rearranged the pipe sizes with respect to the cumulative discharges through water withdrawals at consumer end in equivalent to 5 LPM flow rates (unique) at each households service connections.
- The distribution system as fixed in alignments designed for 30 years of future populations and need for scalable to operate for future higher per-capita service levels with the use of the established pipelines pattern. The systems with this new method are scalable to operate for future higher/ lower per-capita service levels by simply increasing/ decreasing the supply hours according to the demands even in urban and rural areas.
- For maintaining the quality water supply to eliminate the contaminations through the leakage points of the pipelines in DNS byway of arranging continuous water supply around the clock, this transformation may be the next task to tackle in present Indian socio-economical environments.
- This new method is, a unique design pattern with 5 LPM FCV control consumer drawls, scalable for rural to urban per-capita demands and easily convenient to transform of intermittent systems to continuous supply (24x7).
- And also the new method is the best reliable for the continuous supply (24x7) systems ever since the inception of planning of drinking water supply systems to eliminate the problems of unavoidable intermittent supply situations in the future, if any.

The Optimum Design of All Components of Distribution Systems

- **Distribution System:** Pipelines designed for peak hourly demands, peak factor in India may vary 6 to 8 for the continuous (24x7) supply and if the system stabilized after several years of practices.
- But at present conditions of worst situations to avoid the problems in intermittent supply situations consider a unique design pattern for Rural (70 LPCD) and Urban Municipalities (135 LPCD) with restricted drawls by fixing 5 LPM-FCV for each household service connections (drawls equivalent of 4.5 members demand).
- The DNS pipe sizes designed for the daily morning 1 hour supply in Rural with the peak factor 24 for 70 LPCD per-capita demands. Similarly, DNS designed for the daily morning 2 hours supply in Urban Municipalities with the peak factor 12 for 135 LPCD per-capita demands with the provision of 5 LPM flow control valves fixing to all consumers to safeguard the residual heads at all points for more reliability feasible for certain unwanted demand and supply fluctuations even in continuous systems as the systems are at earlier stages.
- **An Important Component is Water Storage Tank:** Elevated Service Reservoir (ESR) with sufficient clear water storage source to deliver water to the Distribution Systems with gravitational pressured flow. The tank bottom portion elevation and the storage capacity established w.r.t. minimum terminal pressure heads required at service level. The design capacity of ESR at village level designed for peak day demands and 1.5 to 2 times of average daily demand whichever is higher for standby provision for reliability supply in un-tear situation breaks from bulk water supply source.
- **Transmission System:** Inflow pipeline systems to fill ESR designed for peak day demand, (minimum peak factor 1.5 for net 16 operating hours) for major trunks and the secondary networks for small villages designed for peak factor of 4 to 2 and based on the power supply interruptions and gravity network feasibility for minimum self-cleaning velocity correspondingly reduce the design operating hours <16 i.e., for the small isolated zone of villages with less population and for scattered located.
- The models for village systems for Indian Environments in intermittent supply situations, given in Figure 1 and Figure 2 are suitable and adaptable for design demands not less than 70 LPCD @ service level.

This article describes a new approach for the design of all components of the distribution system suitable to Indian cities and villages for desired (for limited per-capita supply) quantity supply even in peak hours on a reliable basis to tackle the pressure problems in intermittent supply situations. In this, the system provisions are based on the limited rate of withdrawals restrictions around 5 LPM flow rates at each consumer connections even metering provisioned with control water tariffs. And accordingly, the DNS redesigned/ rearranged the pipe sizes with respect to the cumulative discharges through simultaneous water withdrawals at the consumer-end is equivalent to 5 LPM flow rates at each households service connections."

Conclusions

- In rural India, the general practices of drinking water supply systems, the water is collected to an elevated storage tank directly by available clear water provision of pumping/ gravity from the bulk water supply then the stored water is distributed by gravity from the tank to the consumers at the peak demand periods only, thus, intermittent supply takes place which leads to clear water contamination and improper distribution, etc.
- The consumers are not systematic for use of safe water, at present their mindsets are disturbed with the existing unreliable water supply systems that they are eagerly awaiting for water and try to collecting the total full day demands at once for storage in their houses instead of direct use for instant needs. The planning of Safe Drinking Water Supply Systems at lesser costs may not fulfill the goals in reality with the present unfeasible Rural Socio-Economic Environments. The systems with insufficient provisions may lead to failing the purpose of habitants as they are at the initial stage to change for upgradations.
- The provision of design parameters for all the units planned collectively with enough cushioning for more reliable with respect to the actual system operational environments for providing the safe drinking water supply systems.
- **Distribution System:** Pipe-

lines designed for peak hourly demands, peak factor in India may vary between 6 to 8 for the 24x7 systems if stabilized after several years of practices but at present peak factor 24 to 12 may be considered for Rural (with min 70 LPCD) and Urban Municipalities (with min 135 LPCD) with the provision of 5 LPM flow control valves fixing to all consumers to safeguard the residual heads at tail-end points even in worst situations of certain unwanted demand and supply fluctuations to avoid the problems in intermittent supply situations.

- The continuous direct pumping model utility, which used for the developed countries, may not work in reality for India based on present socio-economic environmental conditions with unreliable quality Power Supply by 24x7.
- Models for village systems for Indian environments in intermittent supply situations, given in Figure 1 and Figure 2 are suitable and adaptable for design demands not less than 100 LPCD at the service level.
- **Transmission System:** Pipeline designed for peak day demand, (minimum peak factor 1.5 for net 16 operating hours) for major trunks and the secondary networks for small villages designed for peak factor of 4 to 2 and based on the power supply interruptions and gravity network feasibility for minimum self-cleaning velocity correspondingly reduce the design operating hours <16 i.e., for small isolated zone of villages with less population and for scattered located.
- **The Design Capacity of Elevated Service Reservoir at the Village Level:** elevated service reservoir designed for peak day demands and 1.5 to 2 times of average daily demand whichever is higher for standby provision for reliability supply in un-tear situation breaks from the bulk water supply.
- The provision of design parameters for all the units planned collectively with enough cushioning for more reliable with respect to the actual system operational environments for providing the safe drinking water supply systems.
- For example, if we are now planning to design for 70 LPCD per-capita demands, the pipe sizes have to be designed for the peak factor of 24 with 5 LPM restricted withdrawals for each household connections, i.e., only 1 hour supply to consumer connections of 4 to 5 members (avg. 4.5*70 = 315 liters) required an average quantity of 300 liters drawls in 1 hour with 5 LPM FCV (5 LPM*60minutes = 300 liters). The designed system for 70 LPCD can also be operated for incremental demands with 135 LPCD by just increasing the time of supply to get the required quantity of (135*4.5 = 608 liters) 600 liters in 2 hours supply. Accordingly, we can increase or decrease the time of supply durations based on the availability of water for intermittent supply situations.
- The same system (if built by the skilled operator as entrusted with the best quality materials) can be maintained for continuous supply (24x7) under the clear water availability provisions for more than the adequate demands (say around 270 LPCD needs 4 hours supply for pipe sizes with 5 LPM FCV withdraw restrictions) for the city of systematic consumers, after a considerable long periods (say 3 years) of habituations for water withdrawals in-times of need basis under the implementations of metering with control water tariff plans for water conservations. Some of the Town Areas, having the individual households demands may be shared with the other economical feasible individual water sources (own tube wells/ open wells in their premises) then the per capita demands on public water systems may be reduced accordingly as water tariffs telescopically rise for rated consumptions. But the demands increases in draught situations and thus the storage provisions for the systems has to be designed for one peak day demands at least 50% more than the rated per-capita norms in additions to the water losses.
- This new method is, a unique design pattern with 5 LPM FCV control consumer drawls, scalable for rural to urban per-capita demands and easily convenient to transform of intermittent systems to continuous supply (24x7). And also the new method with 5 LPM FCV control consumer drawls is the best reliable for the continuous supply (24x7) systems even since the inception of planning of drinking water supply systems to eliminate the problems of unavoidable intermittent supply situations in the future, if any.
- The cost of the distribution system for the model village with 24 peak factor increased the cost by only 20% to 30% more than the cost with peak factor 3 (as per CPHEEO manual) as 60-70% pipe mains sizes unaltered in revised methods due to minimum pipe size constraints. And 20-30% mains, the common main pipe sizes just increase to the next commercial pipe diameters and remaining 10% common mains pipe sizes increase by 50%. And the system head losses are less in new methods with restricted limited drawls as per the increased common main sizes is another advantage for the increase of the system reliability for sustaining the terminal pressures in a long span.

About the Authors

***Rajeshwar Rao Bandari**, Executive Engineer, Mission Bhagiratha, is working from 1992 onwards in the State Government of Telangana, Hyderabad. An expert in water supply Systems design & simulations, he has developed a suitable method for Multi-Village Drinking Water Supply Systems for bulk water supply without valve control/ operations for simultaneous filling of all elevated service reservoirs, and has recently invented a new method for appropriate water distribution systems for the restricted/ limited water per capita supply/ demands to overcome the intermittent supply situations to supply water simultaneously for all consumers.*

***Shiva Ram Bandari** is a Masters Graduate in Mechanical Engineer with Structural Mechanics from BTH, Karlskrona, Sweden. He has expertise in computational fluid dynamics in 2D and 3D mechanical components, simulations, and the newly-developed household flow control valve used for control withdrawal for intermittent water supply situations for public water distribution systems.*

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The distribution systems functioning (operations) in India are not for continuous supply (24x7) and thus not similar to the practice in developed countries as envisaged in planning and design patterns.

POST EVENT

Aquatech China 2019

3-5 June 2019, Shanghai, China

Opportunities in the Chinese water market continue to grow.

AQUATECH CHINA 2019 was a winning mix of business, content and international networking. This 12th edition of Aquatech China turned out even more powerful. Over 2,100 companies exhibited, and over the three event days, a record grand total of more than 84,000 visitors from 95 countries worldwide were counted.

The show brought together industry authorities, key market leaders, international financing institutions and development banks and government officials. The result was an inspiring international exchange with a common goal: discussing growing water business in China and the future of the industry.

Annette Bos, Director Water at RAI Amsterdam spoke at a crowded opening, about how crucial and urgent water issues are around the world and linked them to the constantly growing opportunities for water-related companies in China. The 2,100+ exhibitors included both Chinese and international market leaders such as Grunbeck, Nitto, Pentair, PWG, Samyang, Terra Water Research, Doulton and Rainsoft.

"The opportunities in China are growing constantly. Investments in water to ensure water quality is high on the agenda. Water challenges are connected with a growing sector that seeks innovations and solutions in China and abroad. I am delighted with the results of Aquatech China 2019. There was a positive vibe with full aisles and a lot of attention for the knowledge sessions. Lots of side events were organized and young talent was attracted to learn more about what the water technology sector has to offer. We look forward to building on that success for the next edition in 2020", says Dorien, Sibbel, Exhibition Manager Aquatech China.

Positive Reactions from Visitors

"It was a very useful visit to get valuable products from different companies on the same platform. Very good event to display specialties" - Amar Singh (Manager New Product Development - Okaya Power Pvt Ltd); "It is one of my best exhibitions to find new sellers and manufacturing companies in water treatment systems" - Mahammadreza Shaigani (GM - Nature Rain Company); "One-stop opportunity for the in-depth look into Chinese water technologies" - Patryk Wójtowicz (Research Manager - Savonia University of Applied Sciences); "Very well organized and a nice platform for exhibiting in the future. Sensational innovations in the field of water conservation and purification" - Aniket Lawate (Avantika Enterprises).

Concentrating Industry Knowledge to Add Value to Industrial Water Management

The 2019 Industrial Water Leaders Forum was successfully held on the first day of Aquatech China. The 2nd edition of the forum brought together representatives from government, research institutes, water resource management companies, service providers as well as end-users to share insights on the topic of 'Efficient Water Management, Creating Value for Industry'.

Among the Industrial Water Leaders Forum keynotes were Zhang Tao (Research Associate, Water Environment Institute of Chinese Academy of Environmental Planning), Juha Niemelä (General Director of the Finnish Ministry of Agriculture and Forestry), Christopher Gasson of Global Water Intelligence and James Rekoske (Senior vice president of Ecolab global RD&E and Industrial Segment).

Together they discussed the challenges and the prospects for the industry, the application of smart technology in water management and shared valuable practical experience in the field of water resource management.

The forum was jointly hosted by Aquatech China, CHC Expo, Global Water Intelligence (GWI) and Ecolab, and supported by the Alliance for Water Stewardship (AWS).

Exhibitors Say

"Aquatech China is the largest event that we attend in the region. It maybe the largest water event that exists."

- Kimberly Kupiecki (Global Leader, Sustainability, Advocacy & Communications, DuPont Water Solutions)

"Aquatech China has a magnificent group of people that visit. It's a large volume of people and the kind of people that we want to talk to".

- Don Miller (Regional Director, International, Rain Soft)

"I find Aquatech China a great opportunity for networking, meeting people, having good discussions on different issues concerning water management".

- Kai Kaatra (Ministry of Agriculture and Forestry, Finland)

"Aquatech China offers us access to the highest growing market for technical innovation companies like ours."

- Wayne Byrne (CEO, Oxymem)

Special Attention for Digitalization of Water

China Europe Water Platform (CEWP) organized a bi-lingual seminar for the first time this year and brought experts, utilities, governmental organizations and companies operating in the fields of water supply and wastewater treatment together to discuss developments in smart water. Many practical issues were involved during the seminar, such as "What are the major digital technology disruptors that companies in water business will face?" and "How does this development affect both the Chinese and European water markets?"

The next edition of Aquatech China will be held on 3-5 June 2020. **Smart Water & Waste World Magazine** was an official Media Partner of this event.

POST EVENT

CII GreenCo Summit 2019

3-5 July 2019, Delhi, India

'Innovations will foster environmental sustainability' - 'Going the 'Green' way guarantees success': Experts at CII GreenCo Summit.

CII, WITH THE support of stakeholders, has launched GreenCo rating system, a first-of-its-kind rating system, which holistically evaluates how green a company is and suggests the way forward in pursuing green excellence.

As on date, over 550 companies are at different stages of implementation of GreenCo guidelines, of which 260 companies are already GreenCo rated. GreenCo rated companies have been able to save more than INR 1,257 crores annually through implementation of several environment sustainability projects, apart from gaining other intangible benefits.

To further advance GreenCo movement in the Country, CII organized the 8th edition of 'GreenCo Summit 2019 on 3-5 July 2019 at, New Delhi. Discussions, presentations, and experiences weaved around the theme - 'Green Makes Good Business Sense'.

Padma Vibhushan Dr. MM Sharma, Past President, Indian National Science Academy underlined the need and importance of promoting innovations for environmental sustainability. He emphasized that through innovation, liabilities can be converted to assets like converting waste to wealth, and in the process companies can provide higher value to their stakeholders and for the environment.

VK Yadav, Chairman, Railway Board underlined that Indian Railways has always promoted sustainability as one of its core agenda. GreenCo Rating system has encouraged Indian Railways to pursue manufacturing excellence in workshops and production units. He emphasized that Indian Railways will not rest on laurels and will continue its green work.

Vikram Kirloskar, President CII, emphasized that environmental improvements must be put in the fast track to make the whole country competitive and sustainable. He said that behavioral change is the key to environmental sustainability and every company, every community & every individual should change to make the country sustainable.

Rajesh Agrawal, Member, Rolling Stock, Railway Board, noted that GreenCo Rating has brought in significant changes in the overall approach adopted by Indian railways towards green. The holistic and multi-pronged approach of GreenCo has enabled Indian Railways to take a reality check on energy & water consumption in its workshops and production units.

Dr. Rene Van Berkel, UNIDO Representative, Regional Office India, said that he is glad to see how Indian industry is progressing and transitioning towards greener manufacturing. He emphasized that 'Green' leads to economic competitiveness and will lead to industrial transformation.

Pradeep Bhargava, Chairman, GreenCo Council, CII Godrej GBC, highlighted that, over 550 companies are adopting GreenCo Rating System and GreenCo rated units have been able to save more than INR 1,257 crores annually, through implementation of several environment sustainability projects, apart from gaining other intangible benefits. CII aspires to facilitate 1,000 GreenCo rated units by 2022.

Vikram Kasbekar, Co-Chair, GreenCo Summit 2019 & Executive Director Operations (Plants), Hero MotoCorp said that economic growth should be inclusive with more job creation and must go hand in hand with environmental sustainability for wholesome development. He congratulated GreenCo rated units on achieving phenomenal carbon dioxide savings to the tune of 1.75 million Tonnes per annum.

As part of GreenCo Summit 2019, MoU was also exchanged with Rajasthan State Pollution Control Board (RSPCB) and Indian Texpreneurs Federation (ITF), Coimbatore.

GreenCo Rating Award Ceremony

VK Yadav, Chairman, Railway Board and Vikram Kirloskar, President, CII awarded 38 companies with GreenCo Rating for their excellent performance in resource conservation and environmental management. 11 companies were also recognized with 'GreenCo Star Performers' awards (for sustaining their green performance).

Companies adopting GreenCo rating goes through a rigorous assessment process before being rated as "Green". As on date, more than 550 companies are working on the rating and 260 companies have been rated as 'Green Company'. In the year 2018-2019, 64 companies went through the rigorous assessment process and 38 companies have been awarded with 'GreenCo Rating' at the summit.

CII Environmental Best Practices Award 2019

The Annual CII Environmental Best Practices Award aims to recognize and award the environmental best practices adopted and promoted by Indian companies, as well as facilitates the sharing of best practices. This year, 130 projects from 82 companies submitted their inputs, covering various sectors. On 3rd July 2019, 17 shortlisted companies made their presentation and subsequently were recognized with the award.

Smart Water & Waste World Magazine was an official Media Partner of this event.

POST EVENT

4th GSBS (Global Water Build Summit) 2019

17 July 2019, Mumbai, India

THE 4TH EDITION of Global Water Build Summit (GSBS) and #Time2Leap Awards [Co-sponsored by Scheinder Electric & Co., and Organized by PMI (Pune Deccan Chapter] took place on 17th July 2019 in the Istana Ballroom, Ground Floor at the Hyatt Kalyaninagar, Pune, India.

This was a full-day event where the registration began at 9.30 AM followed by Welcome Speech, delivered by Shyam Bhavsar, Current President of PMI (Pune Deccan Chapter).

The event was attended by the following key speakers:

- Sanjay Pathak, Former Commissioner Planning - DDA (Delhi Development Authority)
- Dhiraj Kumar Pandirkar, Chief Engineer MHADA - Maharashtra Housing Area Development Authority
- Asutosh Limaye, Director Research - Anarock Property Consultants
- Manish Motwani, Director & CEO - RSP India
- Sriram Natrajan, VP Project Management - Radius Developers
- Amitabh Kumar, Senior VP Engineering - Puranik Buikders
- Kumar Ravindra, Design Director - Venkataramanan Associates

Many more industry experts were seen on the panel who gave the keynote address at the event. The event also hosted 150+ construction industry peers alongside 16 unique construction products & solutions brands like Technocraft Industries, Meinhardt EPCM India Pvt Ltd, British Paints, Living Art Interiors, Norisys, Omega Elevators, MFS Formwork, Bronco Buildsmart LLP, and many more innovative and quality brands showcased their solutions at the event.

The event was divided into 3 parts which included conference sessions, B2B meetings, and #Time2Leap awards.

The key takeaways from the conference session included streamlining effective measures for development and re-development of buildings by comparing interstate modules and measures taken into consideration while planning the same. The main areas of discussion circulated around the history of Bombay City, category of buildings, reasons why redevelopment is of key importance today, smart construction technologies saving time and money, stats on how cities are economic engines, key components that elevate projects – with Architects' and Interior Designers' point of view.

The B2B meeting was 2nd part of the summit, where the collected feedback suggested that 2 out of 3 leads introduced to all the brands were unique and each company received a bare minimum of 10 decision-makers of their choice. The summit also hosted gala awards night - #Time2Leap Awards 2nd Edition - which proved to be hugely popular and successful, formulated to honor the innovative and sustainable construction marvels that are changing the dimensions of buildings in India. The #Time2Leap Award winners were as follows:

- Blocher Partners India Pvt Ltd - Most Innovative Architecture Design - Mix Use - Mondeal Heights
- JMC Projects - Residential Property of the Year - Prestige IVY League - Luxury Segment
- Anruna Green Ventures - Best Sustainable Initiator - Waste Management
- Anushree Green Tech - Best Clean & Green Energy Company of the Year
- Global Advertisers - Best Outdoor Advertising Agency - Global Advertisers
- DPA Consultants Pvt Ltd - Retail & Commercial: Business/IT Park of the Year - Bagmane Aquila
- Anil Sharma & Associates - The Taj Hotel & Convention Centre at Agra - Best Architecture Design Hotel, Best Wedding Hotel of the Year
- Simha Associates - Master Planning & Landscape Campus Planning
- Oscar & Ponni Architects - Eco Resort at Amaravati - Master Planning, Waterfront & Other Ecological Projects
- DSP Design Associates - Smart Project of the Year - Commercial - SwissRe
- Opus Architects - Redevelopment Project of the Year - Industrial
- Team One Architects - Best Female Professional of the Year - Varsha Changedia
- Indian School of Business, Mohali Campus - Best Green Campus Award - ISB Mohali Campus

Nitika Shahi, Director of Summentor Pro Business Consultants said that GSBS 4th Edition & #Time2Leap Awards was a fairly new topic of mass interest and the event did do justice to understand the market scenario across India, the major challenges and opportunities that companies can look at while delivering such critical projects.

Here is what the audience had to say about the overall summit:

"This is one of the best events that I have attended with Summentor Pro, the team made a constant effort to ensure everything runs smoothly. Well-organized event. Congrats."

- Anil Bhaskaran, CEO - IDEA Centre Architects

"This is the very first event I have attended and this proved to be very informative for us, the topics & speakers gave complete insights on various markets, the networking sessions were also great! Looking to attend more such informative events."

- Sameer Hastak, GM Operations - LandW India

Smart Water & Waste World Magazine was an official Media Partner of this event.

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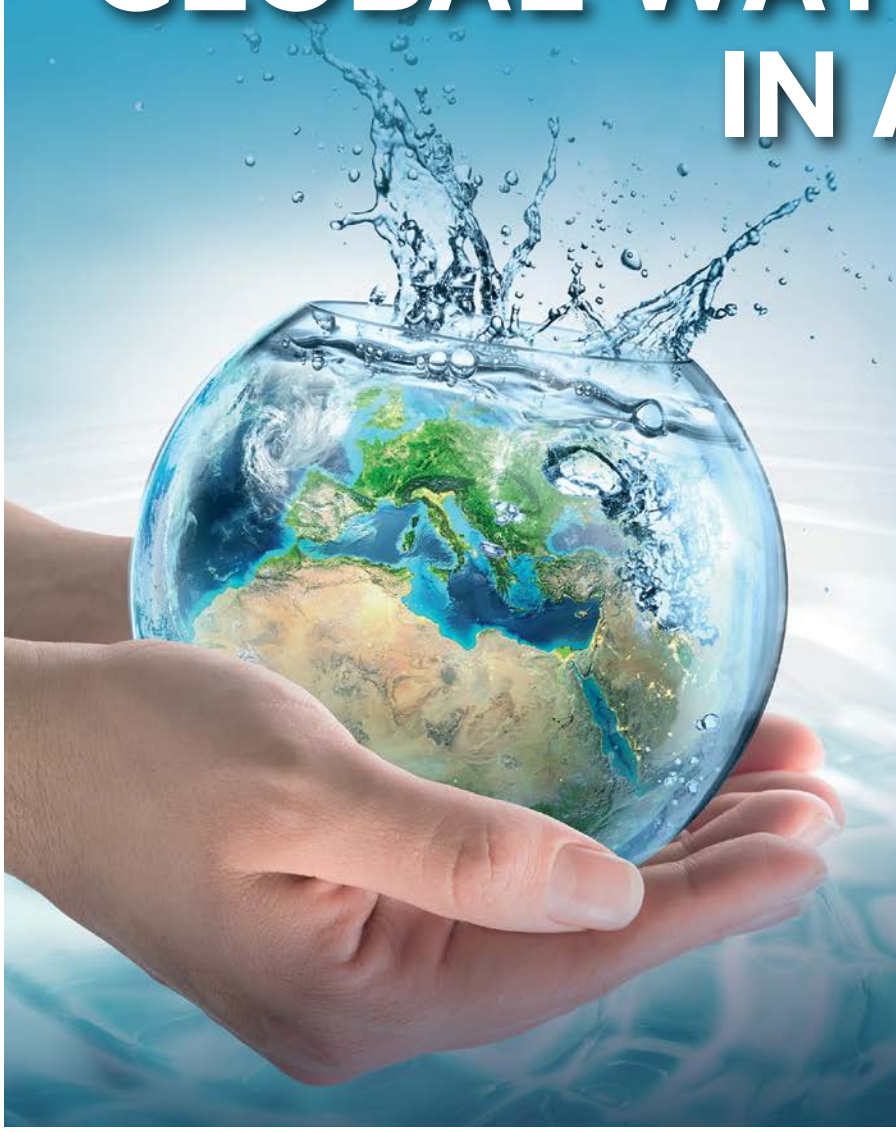

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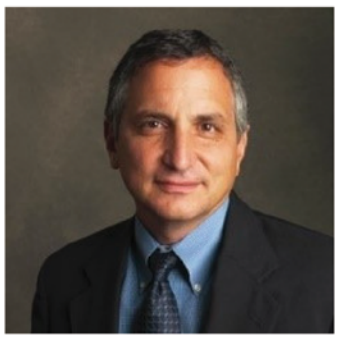

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