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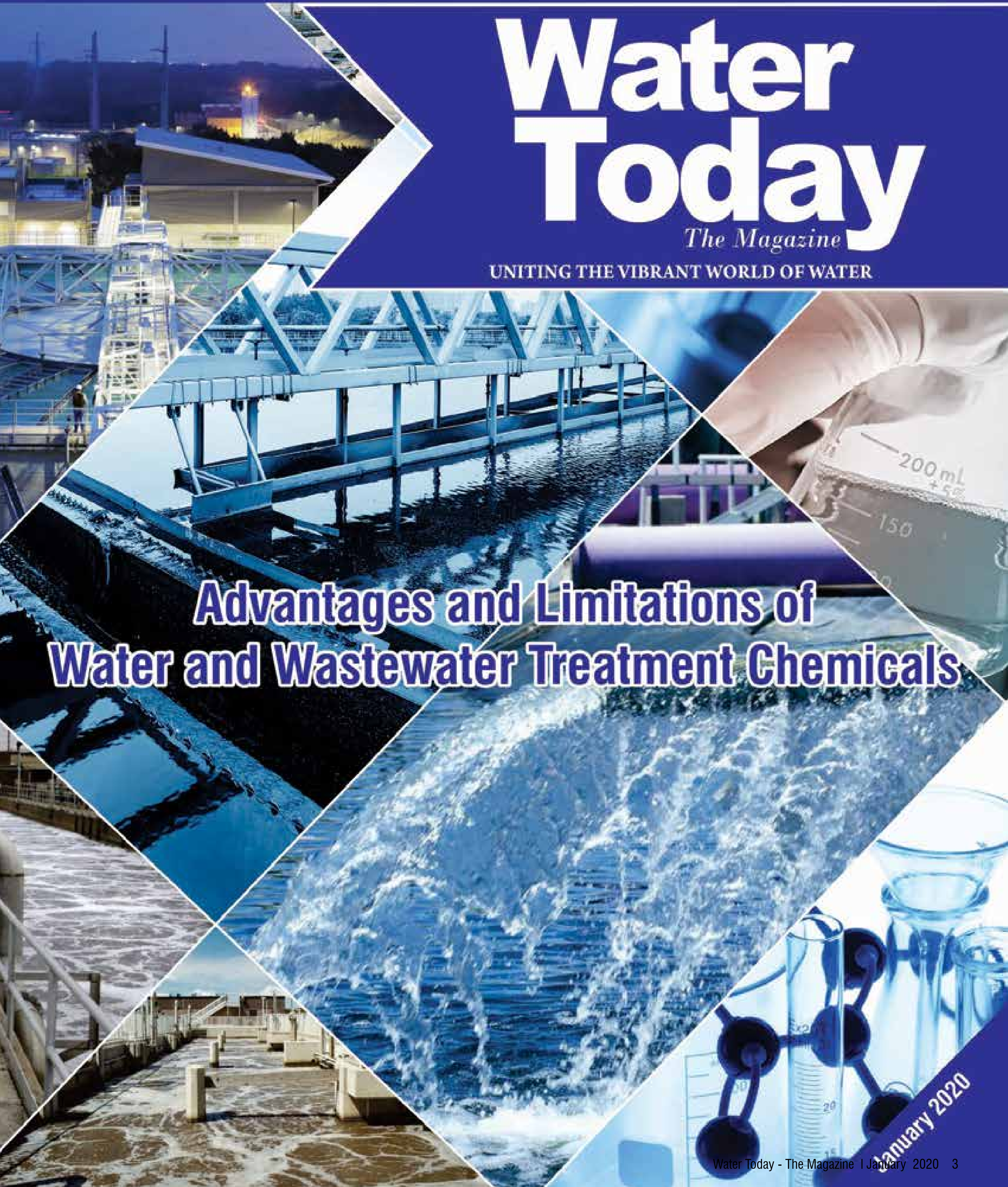
Water Today

The Magazine

UNITING THE VIBRANT WORLD OF WATER



Advantages and Limitations of Water and Wastewater Treatment Chemicals

January 2020

Masthead

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We inspire and encourage perspective authors to write articles, case studies, technical papers and application stories on water and wastewater industry and follow Water Today's Author's guidelines before submitting manuscripts. Write to us at editor@watertoday.org to obtain Author's Guideline.

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UNITING THE VIBRANT WORLD OF WATER - TO PROVIDE A PROACTIVE PLATFORM FOR THE WATER INDUSTRY TO CONVERGE AND WORK TOGETHER IN ACHIEVING SOLUTIONS TO GLOBAL WATER PROBLEMS.

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WATERWORKS

REGULARS

Centre begins training States on piped water quality standard

The Bureau of Indian Standards is preparing the ground for enforcement of piped water quality standards with a workshop for State officials. However, it is not yet clear whether the Centre's own flagship mission to provide piped water to all households by 2024 will implement the BIS standard.

Providing safe drinking water to the common public is a primary requirement for ensuring health, Consumer Affairs Minister Ram Vilas Paswan said on Monday.

He was speaking at a workshop organised by BIS to disseminate information about the requirements of IS 10500:2012, the quality standard. States were informed about the certification schemes and testing facilities required for compliance with it.

Unlike the BIS standard for bottled water, which is mostly produced by private companies, the standard for piped water — largely supplied by government agencies — is not yet mandatory.

Modi launches Atal scheme on groundwater

Prime Minister Narendra Modi launched the Atal Bhujal scheme to strengthen the institutional framework for participatory groundwater management and bringing about behavioural changes at the community level for sustainable groundwater resource management in seven States.

The scheme will be implemented in about 8,350 gram panchayats in 78 districts of Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh.

Of the total outlay of ₹6,000 crore to be provided from 2020-21 to 2024-25, 50% will be in the form of World Bank loan to be repaid by the Central government. The remaining part will be made available via Central assistance from regular budgetary support.

The entire World Bank's loan component and the Central assistance will be passed on to the States as grants. The Prime Minister said the scheme, or the guidelines related to the Jal Jeevan Mission, were big steps in proving the resolve to deliver water to every household in the country by 2024.

He said the country had to prepare itself for dealing with every situation of water crisis, for which the government had been working at five levels.

VA Tech Wabag, Ion Exchange rally over 15% after NGT grim report on water pollution

Shares of VA Tech Wabag and Ion Exchange climbed over 15 per cent on Monday amid reports that the National Green Tribunal directed 100 per cent treatment of sewage entering the rivers across the country by March 31 next year.

The NGT warned that if this is not done, the local bodies and concerned departments of the states and Union Territories (UTs) will be liable to pay compensation of Rs 5 lakh a month per drain in the case of river Ganga and Rs 5 lakh for default in commencement of setting up of sewage treatment plant.

Va Tech Wabag is a multinational player in the water treatment industry with market presence in India, the Middle East, North Africa, Central and Eastern Europe, China and South East Asia through its principal offices in India, Austria, the Czech Republic, China, Switzerland, Algeria, Romania, Tunisia, UAE, Libya and Macao. VA Tech Wabag is also expecting to clock revenues of around Rs 3,000 crore in financial year 2020, according to reports.

While directing that an institutional mechanism be evolved for ensuring compliance of its directions, the NGT asked the chief secretaries of all the states and UTs to monitor the progress of the work, and at national level by the Secretary, Ministry of Jal Shakti with the assistance of National Mission for Clean Ganga and Central Pollution Control Board.

Metrowater to maintain water supply to city at 650 mld

Chennai Metrowater plans to maintain the drinking water supply at 650 million litres a day (mld) till next summer as storage in the city's major reservoirs is only at near half their capacity.

Though northeast monsoon rains helped bring in inflows since October-end, the four reservoirs have only 47% of their capacity. The reservoirs in Poondi, Red Hills, Cholavaram and Chembarambakkam together have a storage of 5,275 million cubic feet (mcft) against their total capacity of 11,257 mcft.

Officials of the Metrowater noted that water supply at the present rate of 650 million litres a day can be maintained till August next year with the available resources. "We will decide on increasing the water supply in January depending on the water level in city reservoirs," said a senior official.

It may be recalled that the water agency had tweeted last month that the city was officially out of water shortage. This followed steady inflow into the major lakes.

French firm Suez working on two water projects in India

France-based Suez SA is working on two water management projects worth 217 million euros (over Rs 1,700 crore) in New Delhi and Mangalore, a company official said.

A waste water treatment plant is being set up in Okhla here at a cost of 145 million euros and will be operational within three years, said Suez Group's Senior Executive Vice President Ana Giros Calpe, who was in the national capital recently.

Besides this, a 72 million euros water distribution project in Mangalore will kick off within a month, Calpe added. The company was awarded the Okhla project by Delhi Jal Board, the governing body for water management, she said adding it will have a capacity of 564,000 m3 /day.

"Once (the project)becomes operational, the plant being set up at a cost 145 million euros will remove 41,200 kg of organic pollutant load per day and 61,600 kg solid load per day from the Yamuna," she said.

Speaking further on the Mangalore project, Calpe said it has been awarded by the civic body of Mangalore and financed by Asian Development Bank.

Will Ensure 24-hour Water Supply in Delhi in Next 5 Years: Arvind Kejriwal

Delhi Chief Minister Arvind Kejriwal said the AAP government will ensure 24-hour water supply to the people in the national capital in the next five years, as Prime Minister Narendra Modi highlighted twice this week the issue of lack of clean drinking water.

Kejriwal said that it would be clean water and people would be able to drink directly from their taps. He was speaking during an event at Kishangarh here to inaugurate the underground reservoir with a capacity of 18 lakh litres. "I have provided water in every household of Delhi in the last five years by laying pipelines. We have a plan for the next five years," he said.

The statement came after Prime Minister Narendra Modi attacked the AAP government over the issue. Earlier in the day, Modi said there is dissatisfaction among people in the national capital over "unclean" drinking water, which, he added is a worrisome issue. Early this month, the PM had said the AAP government had ignored the national capital's biggest problem which is lack of clean drinking water. "We will ensure water services for 24 hours to the entire Delhi in the next five years," Kejriwal was quoted as saying at the event in a statement.

ADB to give $206 mn loan for Tamil Nadu water projects

The Asian Development Bank (ADB) will provide a loan of $206 million to develop water supply and sewerage infrastructure and strengthen the capacities of urban local bodies (ULBs) for improved service delivery in Tamil Nadu. This is the second project loan for the ADB-supported $500 million multi-tranche financing for the Tamil Nadu Urban Flagship Investment Programme that was approved in September 2018.

The programme aims to develop climate-resilient water supply, sewerage, and drainage infrastructure in 10 cities of Tamil Nadu. The first project under the programme, with $169 million financing, is currently under implementation. The Union Government and the ADB signed an agreement for the loan facility on December 2. "The project is aimed at improving the lives of the urban people in the identified cities of Tamil Nadu by providing universal access to water supply and sanitation and improving sewage treatment and drainage systems. Project initiatives are also expected to help the state develop the requisite ecosystem for economic growth", said Department of Economic Affairs Additional Secretary (Fund Bank and ADB) Sameer Kumar Khare.

VaTech Wabag bags Rs 1,187 cr project in Bihar

Water technology company Va Tech Wabag Ltd said it has signed an agreement for a project worth Rs 1,187 crore under the `Namami Gange Programme" (NGP) in Bihar.

In a statement issued, the company said the agreement was signed among National Mission for Clean Ganga (NMCG), Bihar Urban Infrastructure Development Corp Ltd (BUIDCO) and DK Sewage Project Private Ltd (a special arm of Va Tech Wabag).

According to Va Tech Wabag, the project includes development of Sewage Treatment Plants (STP) of 150 million litres per day (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.

The scope comprises Design, Build and Operate (DBO) for a value of Rs 940 crore and Hybrid Annuity worth around Rs 247 crore, totaling Rs 1,187 crore. The STPs will be enabled to produce renewable energy from biogas to run the plants leading to lower operating expenditure.

The company will also be responsible for the operation and maintenance of the STPs and the sewerage infrastructure for a period of 15 years. The project will be implemented by BUIDCO with financial assistance from the World Bank under NMCG.

Water tech firm identifies Chennai as key market

This is due to the persistent water issues Chennai faces and the state government's openness to newer approaches and solutions to address the issues, said H Bala, MD, Xylem India. "Xylem (XYL) is committed to developing innovative technology solutions to the world's water challenges. Our products and services move, treat, analyse, monitor and return water to the environment in public utility, industrial, residential and commercial building services settings. It provides a leading portfolio of smart metering, network technologies and advanced infrastructure analytics solutions for water, electric and gas utilities," he said.

Citing a World Bank study which points to 32 billion cu m of water loss every year in the form of leaks and thefts, Bala said, "Water lost cannot be billed. We are looking at a platform for all the stakeholders – public water utilities and private water professionals of TN to collaborate and deliberate on Non-Revenue Water (NRW) - a challenge that is further amplified by scarcity and climate change."

Grundfos makes splash in Gujarat, plant clocks Rs 230 cr revenue

This will bring to close the two-decade long chapter for the India head, who has steered the subsidiary of the Danish pump major, foraying into Gujarat in 2017 to tap the west market. It has not only stabilised its operations in Gujarat, but also clocked a turnover of Rs 230 crore last year, that, in his words, is already half of the revenues registered by the Chennai facility.

"There is more activity going on in Gujarat and the plant has done fairly well. We have capacity and we are running 1.5 shifts, now. While south continues to be the biggest market for us, local presence in the west and customers having the option of seeing the unit have helped. We do more localisation of stainless steel components in Gujarat, where they are manufactured. One shift is done for most of the assembling, and the balance for testing. So, when it comes to capacity on a single shift basis, we are running full," says Ranganath NK, MD, Grundfos Pumps India, clarifying the factory had exceeded expectations, but not when it came to sales.

According to him, the south, comprising the five states were powerhouses compared to rest of India, but Gujarat and Maharashtra were larger markets which could not be ignored. "Sourcing talent, unlike in Chennai, is an issue. People in the western region are more inclined towards entrepreneurship. Overall attrition is less than 10 per cent," Ranganath seeks to point out, as he throws light on the year-on-year growth of Grundfos India, that is a 400-member strong entity.

New channel partner for SPX Flow in Australia

SPX Flow has appointed Dynapumps Pty Ltd as its channel partner for APV pumps, valves and mixers as well as Waukesha Cherry-Burrell (WCB) pumps and valves in the Queensland, Victoria and Western Australia territories. The announcement comes just weeks after SPX Flow named AME Pump Specialists as its new channel partner in South Australia for its APV and Waukesha Cherry-Burrell (WCB) product lines.

Dynapumps offers a portfolio of pumping packages. With the addition of the APV and WCB product lines, it will now be providing complete hygienic solutions, incorporating valves, centrifugal and positive displacement pumps designed specifically for use in sanitary applications.

Dynapumps' services include project development, manufacturing and commissioning to meet specific installation needs. The company will now add sales and application engineers to extend its customer reach in support of this new partnership.

Toray looks to the future with new R&D centre in Japan

Toray Industries Inc has inaugurated an R&D Innovation Center for the Future at its Shiga plant in Otsu, Japan. The new facility will lead Toray's global research as its functional materials headquarters. It will engage in research and develop technologies through collaboration with the company's domestic and overseas production and sales units creating advanced materials, devices and systems in advanced medical, renewable energy, filtration and separation systems, and other eco and lifestyle innovation areas.

The centre has two buildings: the Integrated Research Building will undertake integrated research to generate ideas for materials, ideas and systems, and the Demonstration Research Building will undertake empirical research through prototyping, assessments and demonstrations based on those ideas. Toray says that its new facility will serve as an innovation hub, through its international conference hall, exhibition and demonstration areas, and open laboratories. It will also promote strategic open innovation by engaging and collaborating with academia and key partners in diverse fields.

Akihiro Nikkaku, Toray president, said that the centre will play a vital role in helping resolve such global issues as climate change, water shortages, and resource depletion. "I also look for the facility to serve as a vehicle for joint research and development collaborations with universities and public research institutions around the world, innovating world-class technologies."
The Shiga plant is where Toray began in 1926.

Light waste water pumps in hard rock

The manufacturer's focus is particularly on the dewatering pumps of the KTV series. It is one of the successful models of the Japanese manufacturer and is regarded as an all-rounder for construction sites. A key factor is the low weight that Tsurumi achieves with a die-cast aluminium housing. Many customers therefore like to use the KTV, especially as it makes transport to different locations easy. However, the lightweight construction reached its limits occasionally in environments with highly abrasive water, such as mining, tunnelling and special civil engineering. Tsurumi generally recommends other pumps for these applications.

The manufacturer took action and formed a special team. They investigated the mechanical stress, especially on the oil housing, fixing disc, pump housing and wear plate. The focus was on the use of the pumps in very demanding environments such as hard rock. New wear parts were developed in a modified design with a different Shore hardness value. In addition, the parent company in Japan manufactured the oil housing with a greater wall thickness. The upgraded pumps proved to be considerably more resistant: In practical testing in a German tunnel project, the lifetime was extended from five weeks to five months. Further operations in several tunnels, including Austria, delivered even better results. The conversion kit was released.

Aiimi and UK Water Partnership join forces to build smarter water management future

Data and information management expert Aiimi has joined the UK Water Partnership, affirming both organisations' commitment to helping drive transformative change in the UK water industry. The collaboration will see both parties work together to tackle key water management challenges in an era where sustainability is more important than ever before. The bulk of Aiimi's work will align with the Partnership's Digital Water initiative, which aims to nurture digital innovation throughout the industry. This encompasses all elements of the water ecosystem, including resource management and treatment technology, flood resilience, operations management and resource recovery. Aiimi will be leveraging its previous experience with a number of UK water companies – covering both technology and consulting – to assist the Partnership in its ongoing efforts.

Commenting on the new collaboration, Steve Salvin, CEO of Aiimi, said, "We are honoured to become a part of the UK Water Partnership and its Digital Water initiative, building on the previous experience we've had working with water companies across the country. Water is an area where we see not just a number of opportunities to grow our business, but also an area where organisations can have a positive, tangible impact on the lives of millions of people.

DuPont to buy closed circuit reverse osmosis company Desalitech

DuPont has signed an agreement to buy Desalitech, a closed circuit reverse osmosis (CCRO) company. Financial details of the deal have not been divulged. The deal, which is subject to customary closing conditions and regulatory approvals, is likely to complete in January 2020.

DuPont Safety & Construction president Rose Lee said, "As a global leader in innovative water solutions, we are committed to delivering ways to solve water challenges around the world. "This acquisition in the high-growth water purification space reinforces our strategic intent to provide a robust portfolio of technologies to meet our customers' current and future challenges while advancing our corporate commitment to sustainability."

DuPont provides water purification and separation technology including reverse osmosis, ion exchange resins, and ultrafiltration. The acquisition of Desalitech is part of DuPont's strategy to boost growth and innovation through new manufacturing facilities, technologies, and geographies. With the acquisition, DuPont gains access to Desalitech's patented process technology, which features standardised design and is operated using proprietary software. Furthermore, the purchase will help DuPont to expand its portfolio and further reduce the lifecycle cost of water purification and reuse.

SUEZ Expands Its Ultrafiltration Global Membrane Manufacturing Center Of Excellence In Hungary

As a result of increased global demand for membrane technologies used in the water sector, SUEZ will invest approximately €30M to expand its state-of-the-art facility in Oroszlány, Hungary, where it manufactures ultrafiltration membranes for water and wastewater treatment. Hungarian Minister of Foreign Affairs and Trade Peter Szijjártó and SUEZ - Water Technologies & Solutions CEO Yuvbir Singh met to commemorate the expansion.

The plant is one of the largest in the world dedicated to the production of hollow-fiber ultrafiltration membranes. SUEZ's ZeeWeed membranes separate particles, bacteria, and viruses from water, and are used for drinking water, wastewater, tertiary and water reuse applications. The ZeeWeed 500 technology is the building block of many advanced industrial and municipal wastewater treatment facilities, which have chosen MBR over conventional methods of treating wastewater to better meet stringent wastewater discharge regulations, and to conserve freshwater supplies through water reuse.

Ses Water Announces Appointment Of New Chief Executive Officer

Ian Cain is currently the Chief Executive Officer of iSupplyEnergy (part of the Vattenfall group), a role he has been in for the last 14 months. Prior to this he was the Managing Director for Retail and Group Customer Service at Thames Water between 2013 and 2017 and has held a number of senior customer service and transformation positions at British Gas (Centrica). Commenting on his new position Ian said: "It's a real privilege to be given the job of leading SES Water at what is a crucial time for water companies across the country. The company's proposed business plan is the most ambitious in its history and we need to ensure we achieve what we have promised for our customers and continue to set new standards for the industry. I look forward to joining the team in a few weeks' time and building on all the good work that has led to SES Water's very positive track record and innovative reputation, proving that a small company can be a leading performer in the industry."

Commenting on the announcement SES Water Chairman Jeremy Pelczer said: "The Board and I are delighted to welcome Ian to the company, who brings with him a wealth of experience from the energy and water sector. During the recruitment process I was particularly impressed with Ian's unwavering focus on the importance of the service we provide to our customers and his respect for our achievements and reputation. I look forward to working with Ian and continuing to ensure we go from strength to strength as we make the most of new opportunities to deliver for our customers, employees and shareholders. I am also pleased to take this public opportunity to thank Anthony for his many years of leadership and commitment and to wish him a long and happy retirement."

Zero Brine launches first pilot in Rotterdam

Circular industrial processes are essential to develop a sustainable, low carbon, resource efficient economy in the EU. Recovering all resources from wastewater enhances the preservation of resources and security of supply. Demineralised water is an essential commodity required for many industrial processing facilities in Rotterdam port. This water is provided by the Evides DWP, one of the largest demineralised production facilities in Europe. The current technology uses ion-exchange softening combined with reverse osmosis (RO), along with other technologies. The Rotterdam port technologies have been provided by project consortium members including the Dutch water treatment company Lenntech (nanofiltration), the National Technical University of Athens (evaporator) and the University of Palermo (crystallizer). The technologies have been developed and tested both in laboratory and at bench-scale, as well as on an individual basis over the past year at industrial pilot-scale.

Everbright Water awarded two wastewater treatment projects in China

Everbright Water has recently secured Ji'nan Tangye New Area Wastewater Treatment PPP project and Zibo Northern Wastewater Treatment Plant Expansion Project in Shandong Province, China, with a total investment of approximately RMB396 million.

Tangye New Area Project will be invested in, constructed and operated by a project company jointly established and led by Everbright Water based on a PPP (Public-private Partnership) model, with a concession period of 30 years (construction period inclusive). Everbright Water holds a 99.9% stake in the project company.

The project will be mainly responsible for providing wastewater treatment services to the Tangye New Area in the Licheng District of Ji'nan City. With a total investment of approximately RMB313 million, Tangye New Area Project has a total designed daily wastewater treatment capacity of 45,000 m^3 (comprising 25,000 m^3 for phase I and 20,000 m3 for phase II). The discharged water will comply with the national Grade 1A standard according to the Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB18918-2002) (the "National Grade 1A standard"), with some of the discharge indicators superior to this standard.

Scottish Water pilot uses earthworms in wastewater

Part of an EU-funded project called Innoqua, which is being trialled in 11 countries including Scotland, the pilot will measure the effectiveness of earthworms, water fleas and microalgae as a carbon neutral method of treating wastewater. The Scottish Water pilot has recently begun in the small rural community of Littlemill in Nairnshire and will run alongside the existing treatment plant.

Project manager, Anna Baran, said: "The technology we are trialling basically replicates a process which happens naturally within soil, but we are using it to clean wastewater. She added:

"The first stage of treatment involves a tank filled with earthworms – the worms eat the larger particles of organic matter in the wastewater, before it is added to a second tank containing water fleas and microalgae which remove the finer bits of organic matter."

The objective of the project is to provide a decentralised, ecological wastewater treatment for use in rural communities as well as industries such as agriculture and aquaculture.

Siltbuster provides water treatment solution for Welsh Water project

The temporary modular water treatment solution was designed by Siltbuster's team of technical engineers and deployed in two weeks. Equipped with inlet monitoring telemetry and monitoring systems, Siltbuster's system included three containerised dosing units, three 30m^3 multistage reaction tanks, 18 HB50 Clarifiers and a 30m^3 sludge storage tank with related pipework.

The system was used by JN Bentley during the Castell Nos Reservoir infrastructure's maintenance work. The reservoir is located in South Wales. During the course of maintenance work, the reservoir required a complete drain down and an alternative raw water supply from a nearby reservoir for uninterrupted water supply.

JN Bentley was also required to complete the project within the time frame outlined by Natural Resources Wales. Furthermore, the water main was inactive for over ten years and needed restoration. The potable water treatment works and the alternative source are connected by the water main. It required a pipe flush at a flow rate of 750m3/hr for a minimum of six hours to remove the suspended solids. JN Bentley Works Manager Jaes Stanley Ball said: "This was a challenging project, but Siltbuster was professional from the initial delivery of its documents through to the actual implementation of the system on-site.

Porvair expands range of compressed air filters

The Porvair Filtration Group has further expanded its range of microfiltration products with the launch of seven new metallic Compfil filters for use within process air and gas applications. The filters are used in industries including sterile applications within water, chemical, pharmaceutical and food and beverage manufacturing.

The Compfil PD, WD, WV, ST and PC are all part of a range of sterile depth filters for process air and gas applications. These pleated depth filters consist of a three-dimensional borosilicate depth media, achieving a void volume of 95%, ensuring a high containment capacity at high flow rates and low differential pressure.

The Compfil SF is a range of sintered steel sterile filters for gases, liquids and steam and is designed for removal of particles from gases, liquids and steam. The SF consists of a re-generable isostatically pressed filter cylinder made from sintered stainless steel. The retention rate ranges from 1µm to 25µm.

PFRO: Innovative process for water reuse

The Pulse Flow Reverse Osmosis (PFRO) is a new way to operate RO, chloramine-free. It allows us to achieve high recovery and very high flux, all in a single stage, thus offering significant CAPEX and OPEX advantages. Water scarcity around the world increases the attractiveness of reusing reclaimed effluent, both in the municipal and industrial sectors.Traditional water reuse processes typically include reverse osmosis (RO) that operate at a recovery of 80-85%, using 2-3 stages in order to keep the required minimal cross-flow velocity.

This creates an inherent head loss which is the result of the feed water that flows through the system and leaves as brine. This is basically a 'parasitic' flow that doesn't contribute to the permeate production; it only serves the hydraulic purpose of maintaining adequate cross-flow velocity. This loss grows as fouling builds up on the membrane surface and spacers. In addition, chloramine is normally dosed in order to control biofouling formation on the membranes. This results in the formation of disinfection by products, such as N-Nitrosodimethylamine (NDMA), Haloacetic acids and Trihalomethanes. NDMA is an organic contaminant suspected as carcinogenic.

Adler and Allan announce exclusive partnership with Bradbury Group to supply and install market leading flood doors

Adler and Allan, the UK's largest environmental and risk reduction specialists, has announced an exclusive partnership with the nation's leading provider of steel doors and physical security solutions, Bradbury Group, to supply and install its market leading range of flood security doors to businesses in the UK.

Specifically designed to meet the needs of the utility sector, the M2MFL range provides an ideal solution for unmanned and critical locations where both security and flood protection measures are required. The announcement follows a series of floods across the UK earlier this month, with some areas enduring a month's rainfall in one day and more than three dozen flood warnings issued across the country.

As a leading flood alleviation solutions provider, Adler and Allan offer a variety of services designed to establish flood risk and then mitigate from flooding; including professional surveys, flood risk assessment, flood defences and civil engineering measures.
Mark Griffiths, Head of Asset Protection at environmental risk reduction firm, Adler and Allan, said: "Bradbury Group's expertise lies in the security and protection of assets, coupled with our focus on environmental and risk reduction our values and ethos closely match.

Northumbrian Water launches global innovation platform

Northumbrian water is opening the innovation floodgates to the whole world with the launch of its new ideas sharing platform 'Amplify'. Amplify is a shared space where anybody from across the globe can come together to help solve big problems, pitch new ideas and innovate together. The website will see the North East Water Company post a series of big real life challenges and then open them up to the rest of the world to try and help solve them. People can suggest ideas, pitch their products, ask questions and interact with other innovators and creators all within the Amplify website.

Each challenge will be owned by an expert from within Northumbrian Water and they will monitor responses, engage with users and pick up and run with the most promising ones. There is potential financial backing and funding to develop and trial the best ideas and anyone can register and take part in the challenges. Northumbrian Water's Head of Innovation, Angela MacOscar, said: "We believe whole-heartedly in open innovation. We love new ideas that will make a difference to our customers' lives and when we find them, we will back them completely."

Culligan And AquaVenture Announce Definitive Merger Agreement

Culligan, the innovative brand in consumer-focused and sustainable water solutions and services, and AquaVenture Holdings Limited (NYSE: WAAS) ("AquaVenture"), a leading multinational developer and provider of sustainable Water-as-a-Service® (WAAS®) solutions, announced they have entered into a definitive agreement under which Culligan will acquire AquaVenture for $27.10 per share in an all-cash transaction valued at approximately $1.1 billion, including AquaVenture's net debt.

AquaVenture has grown to become one of the leading WAAS solution providers in North America, the Caribbean and Latin America. The company offers point-of-use filtered water systems and related services to more than 55,000 institutional and commercial customers across the U.S. and Canada, and desalination and wastewater treatment solutions to governmental, municipal, industrial and hospitality customers throughout the Americas. The transaction will result in AquaVenture joining Culligan's leading consumer water service and solutions platform as a privately held company. Under Culligan's ownership, AquaVenture will continue its focus on providing world-class service and innovative water treatment solutions for its customers. "AquaVenture is a leading player in water purification solutions with a strong record of innovation," said Scott Clawson, CEO of Culligan. "We are excited to work with the AquaVenture team and look forward to the many opportunities ahead."

Techtrol Bicolor Multiport Level Gauge - TBLG

TBLG is used to measure and monitor steam and water level in high pressure boilers. The level or presence of water is indicated by green color and steam by red color in various ports of multiport gauge.

- It is designed for the max pressure & temperature of 70 kg/cm², 300 ⁰C respectively.
- The CC distance of the gauge is available from 600 mm (5 ports) to 1500 mm (21 ports).
- It is available in CS or forged SS304 or SS316 material

Pune Techtrol Pvt. Ltd.
Code: A100

Vertiflo Pump Series 2100

The Series 2100 has capacities to 1300 GPM, heads to 112 ft TDH and is available in 3-in, 4-in and 6-in sizes. It is capable of handling solids with up to 3-in diameter spheres. Additionally, the suction lifts to 25 ft. The Series 2100 is designed for a wide range of applications including liquids entrained with solids, general industrial applications, pulp and paper, mining, meat packing, raw sewage, sludge, slurries, trash and wastewater. The standard construction of the pumps is all iron and all CD4MCu, a high-grade duplex stainless steel for abrasives handling

Vertiflo Pump Company
Ref Code: A101

Intrinsically-Safe Wastewater Data Logger Offers GPRS Telemetry

Water and asset monitoring specialist HWM has developed an intrinsically-safe data logger for wastewater applications. When combined with the SonicSens 2 level sensor or third-party sensors, the new Intelligens WW can be used to monitor open channels, combined sewer overflows, storm drains, storage tank levels and flood warning alarm sensors. The standard Intelligens WW system comprises one or two ultrasonic level sensors with an ATEX Zone 0-certified data logger. The unit's multi-input functionality means it can also be used in combination with digital pressure or depth sensors, as well as simple level or temperature sensors. Data and alarms are transmitted via GPRS, with an option for SMS backup. A 3G modem variant is also available.

HWM Water Ltd
Ref Code: A102

Polyacrylonitrile Ultrafiltration Membranes

Synder Filtration recently released a new line of polyacrylonitrile UF membranes specially designed for oil separation and removal in wastewater treatment applications. These membranes join the broad range of molecular weight cut-offs available within Synder Filtration's ultrafiltration product line, and consist of PX (400kDa), PY (100kDa), and PZ (30kDa). The development of these membranes was driven, in part, by the rise in discharge regulations by environmental agencies. These strict regulations have pushed manufacturers to implement various forms of oil removal technology in order to reuse and discharge large volumes of wastewater.

Synder Filtration
Ref Code: A103

For more details on products contact info@watertoday.org

INTERAQUA TOKYO 2020

InterAqua 2020, the 11th International Water Solution Exhibition, is a unique exhibition for water industry which will showcase a material, component, and apparatus which are indispensable in the process of water reuse, industrial cleaning, drainage, and recycle use for water and its energy saving and cost reduction. Against the backdrop of the ever-growing global need for quantitative and qualitative solutions in the water industry, various key players from Japan and overseas will gather to open up a path to the next generation in water-related business. The exhibition will offer an opportunity for participants to sow seeds of innovation, seek out technological cooperation and engage in business alliances.

For more details log onto: https://www.interaqua.jp/eng/

World Water-Tech Innovation Summit

The 2020 World Water-Tech Innovation Summit brings together 300+ water leaders for two days of collaboration, dialogue and deal-making. Networking is made easy, including advance connections with speakers and delegates via a 1:1 meeting system and a dedicated networking hub throughout the summit. Each year the World Water-Tech Innovation Summit is produced in partnership with the UK Department for International Trade and attracts large delegations from Europe, Asia, North America, South America, the Middle East, Africa and Australasia who come to showcase best-in-class innovation and form lasting business partnerships.

For more details log onto: https://worldwatertechinnovation.com

Event Zone

MENA WATER SUMMIT 2020

The MENA Water Summit will focus on developing effective plans establishing advanced water management techniques to cope up with Kuwait's 2035 vision and current water situation in the MENA region to ensure water security and sustainability for all. Kuwait is shifting to Innovative Water Treatment and Renewable Desalination Technology, as more than 95% of potable water comes from desalination - an energy-intensive technology burning fuels for drinking water and treatment of wastewater for domestic and irrigation purposes.

For more details log onto: http://www.wpsummits.com/menawater/

WQA CONVENTION AND EXPOSITION 2020

The WQA Convention & Exposition is the premier water treatment industry education, sales and networking event. The convention helps dealers, manufacturers and consultants find the VISION you'll need in meeting the challenges of our growing industry.

At the 2020 Convention & Exposition, you can:
• Learn about the latest research in water quality
• Pick up some Continuing Professional Development credits toward recertification
• Develop new skills for managing your business
• Take your professional certification exam -- at a discount!
• Get to know your peers at the New Attendee Breakfast or the Opening Reception

For more details log onto: https://www.wqa.org/convention

Aerzen Turbo at 200 - S10

Most efficient when operating near its design point and therefore performs cost-effectively in applications with narrow swings in turndown. The turbo, however, has a higher initial cost than its rotary lobe and hybrid counterparts. For applications with lesser variations in operating conditions, the additional cost can be compensated for by lower energy consumption.

Aerzen
Ref. Code: BO 100

Ipex PVC and CPVC Sch80 Pipes

Clear-Guard™'s fail-safe, fully pressure rated clear containment system allows for easy detection of leaks and eliminates the risks associated with piping aggressive chemicals overhead. The Clear-Guard is factory pre-assembled and supported and restrained by the IPEX patented Centra-Lok and Centra-Guide systems. The easy detection of leaks is facilitated by clear PVC, allowing for the visual monitoring of liquids passing through the pipe, determination of the direction of flow and/or colour of liquids, as well as quick identification of primary piping for high purity piping runs. The Clear-Guard also stands out as there is solid containment without the use of sealant, unlike products from other companies.

Glynwed Pipe Systems (Asia)
Ref. Code: BO 102

Big Kubota Pumps

Aussie Pumps 3" & 4" Kubota diesel powered pumps are engine match tested to ensure performance and smooth running even under load. The pumps are powered by Kubota's beautiful 9.5 hp OC95 electric start air and oil cooled diesel engines. The oil and air cooled design means that the engine runs cooler than conventional air cooled engines, is quieter and provides an excellent fuel economy. Both the 3" and 4" pumps use both the same Kubota engine, match tested and approved.

Kubota
Ref. Code: BO 101

Scadawatch Suite

Designed for Water and Wastewater Utilities of Any Size, Expanded Suite Gives Users More Power to Create Complete Online Role-Based Dashboards as well as Electronic and Paper Operational and Regulatory Compliance Reports The Suite combines the company's industry-leading geocentric online business performance visualization and analytics-driven dashboard solution with complete user-level customised paper and electronic reporting capabilities. With SCADAWatch Suite, utilities can now consolidate key performance indicators to effectively monitor critical assets, quickly spot changes and patterns, identify areas that need immediate attention, instantly create internal and regulatory reports, and optimally manage operations — without adding to IT overhead and with little or no training.

Innovyze
Ref. Code: BO 104

DuPont Water Solutions Finalizes Acquisition of inge GmbH BASF's Ultrafiltration Membrane business now part of DuPont Subheading

DuPont (NYSE: DD) announced that after signing agreements to acquire the Ultrafiltration Membrane business from BASF –inge GmbH – including ultrafiltration and membrane technologies – the acquisition has been finalized and is now in place.

"As a global leader of innovative water solutions committed to investing in specialty solutions, the integration of inge®'s technologies extends our water purification capabilities and helps meet growing customer demand for ultrafiltration," said Rose Lee, President, DuPont Safety & Construction. "inge® is an ideal fit for enhancing our ability to design tailored, integrated solutions for drinking water, and industrial and wastewater treatment applications."

inge GmbH industry-leading multi-bore PES ultrafiltration technology complements DuPont's leading portfolio of water purification and separation capabilities. The product lines will join DuPont's trusted FilmTec™ Reverse Osmosis and Nanofiltration Membranes, "Integraflux™ / Integrapac™ Ultrafiltration Portfolio, and Amber series of Ion Exchange Resins to provide more options for customers.

"Today marks a new trajectory for our business," said HP Nanda, Global Vice President and General Manager, DuPont Water Solutions. "Our combined, broader filtration portfolio further boosts our position as a market shaper, and we look forward to combining our strengths to be bolder, better and stronger for our customers and the marketplace."

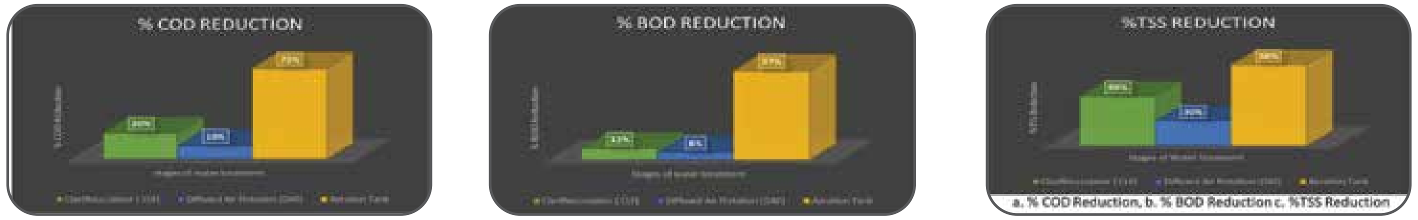
GUTERMANN launches the world's first NB-IoT-based water leak detection technology

GUTERMANN, a global leader in leak detection solutions for the water industry, announced the launch of ZONESCAN NB-IoT – the world's first water leak detecting noise logger based on Narrowband Internet of Things ("NB-IoT") for permanent monitoring of water distribution mains. NB-IoT is a new cellular communication standard optimised for machine-to-machine data communication in smart cities. NB-IoT significantly outperforms conventional 3G and 4G technology, as it consumes 5-10x less power and has significantly improved underground coverage. Telecom operators worldwide have announced plans for complete NB-IoT coverage and are in the process of activating their NB-IoT antennas throughout their networks.

The ZONESCAN NB-IoT logger is GUTERMANN's first cellular logger and complements the company's RF-based ZONESCAN ALPHA system which has established itself as the leading fixed network technology and is used in over 300 cities around the world. ZONESCAN NB-IoT is a correlating system which means that the cloud-based ZONESCAN NET software automatically compares the data of all neighbouring sensors every day to identify even quiet leaks whose existence are not recognised by individual loggers. A Correlation Indicator provides information about the area in which the leak has been identified, neatly displayed on a Google Maps™ enabled user interface. ZONESCAN NET also lets users see and manage their leak detection infrastructure, perform advanced leak analysis, import and display their GIS data, and change settings such as recording times, alarm thresholds and more.

Lucas Grolimund, CEO of GUTERMANN comments: "We are excited about the launch of this product because we see an enormous potential for it given the connectivity and power properties of the NB-IoT technology. We're happy to once more lead the way in advanced fixed network leak monitoring solutions. Our hope is that the ZONESCAN NB-IoT logger will make permanent monitoring of networks more accessible to utilities due to its cost, ease of installation and compact design. It should therefore contribute to the rapid growth of technology-enabled smart water networks, helping to consistently reduce and maintain lower water loss levels."

Effluent Treatment in CETP's Major Issues & Challenges



a. % COD Reduction, b. % BOD Reduction c. %TSS Reduction

A case study of how effluent is generated mainly from dyes, textile industries, and specialty chemical industries.

By Shreya Athalye, Abhishek Gupta, Sachin Shirke

Water is the fundamental resource to maintain life on the earth. As a very small portion of total water resources (1.7%) are useful for domestic and industrial purposes, conserving water resources becomes our utmost responsibility. The rapid industrialization has increased water consumption in multiple folds. The Union Ministry of Water Resources and the Central Pollution Control Board (CPCB) reported that the industrial sector accounted for about six to eight percent of the total freshwater abstraction.

According to the World Bank, the current industrial water use is about 13 percent of the total freshwater in India, and it will grow at a rate of 4.2 percent per year, rising to 228 billion cubic meters by 2025(http://oneindiaonepeople.com/industries-and-water-use/). In proportion to the increasing demand for clean water, the industry generated wastewater has been increasing exponentially, challenging the efficient use of water resources.

The traditional individual effluent treatment plants (ETPs) have limitations due to lack of space, resources, capital cost, and specialized workforce for operation and maintenance (Pathe et al. 2004). These limitations ultimately give rise to the ignorance of the industries towards the wastewater treatment and proliferates the release of the untreated wastewater into the natural water resources and thus, further polluting the water resources.

These factors ultimately contribute to the eminent problem of water scarcity. To control water pollution and to avoid water scarcity, the concept of the Common Effluent Treatment Plant (CETP) has emerged and established by the Government body along with the Central and Regional Pollution Control Board at different Industrial Estate.

What is CETP?

Common effluent treatment plants (CETPs) are treatment systems designed explicitly for collective treatment of effluent generated from small-scale industrial facilities in an industrial cluster(Vyas et al. 2011). The collection and treatment of the effluent from multiple facilities results in varying qualities and quantities of effluent at CETP (Vyas et al. 2011). Although equalization tanks present as a part of primary treatment in every CETP act to cause steady-state mechanisms in the effluent for further processing, there are a multitude of possible reasons for failure, including shock loads, damage to mixers, and clogging of pumps and plumbing systems, to mention a few(Garcia et al. 2013; Du et al. 2014). This situation leads to non-homogenized effluent flowing to subsequent units, causing non-uniformity in the entire process in general, and leading to substandard quality of treated effluent.

Advantages of CETP

1. CETP is an economic system which saves in Capital and Operating cost of treatment plant.
2. CETP resolves the problem of the availability of land which is otherwise unavailable for individual treatment plants.
3. The Contribution of nutrient and diluting potential makes the complex industrial waste more amenable to degradation.
4. The neutralization and equalization of mixed waste makes its treatment techno-economically viable.
5. Professional and trained staff can be made available for the operation of CETP, which is not possible in the case of individual plants.

6. CETP facilitates easy disposal of treated wastewater & sludge.
7. CETP reduces the burden of various regulatory authorities in ensuring pollution control requirements.

Challenges of CETP

1. To achieve high reliability, the variability in the quality of the raw water entering the CETP should be monitored and controlled.
2. Biological treatment units can be optimized by maintaining a healthy biomass and F/M ratio. The recalcitrant compounds in the effluent should be identified and prioritized.
3. Frequent disruptions in the conveyance system resulting in overflow of effluent.
4. Shock loading and overloading of the CETP.
5. Corrosion of machinery and equipment, breakdowns, below-rated capacity performance of pumps, aerators.
6. Inefficient performance of various treatment units of a CETP much below the designed capacity.
7. Inconsistent results in the effluent discharged after treatment.
8. Difficulty in management and disposal of sludge generated.
9. Higher cost of treatment than anticipated.

Chembond Water Treatment Technology for the CETP

The Chembond group has been working in the area of wastewater treatment since its establishment in 1975 and has developed an expertise to provide complete water treatment solutions for all the types of waste as well as raw water. With the understanding that each industry, as well as its water, has specific characteristics and hence, we have developed a range of tailor-made solutions for our customers. The synergetic effect of our physio-chemical and biological treatments provides end-to-end solutions to the wastewater problems. Our area of specializations/expertise involves,

- Coagulants and flocculants for COD reduction
- Specialize Ultra High Molecule Weight Flocculant for sludge dewatering
- Antifoaming/ Defoaming Agents for Biological Process.
- RO Antiscalant and cleaner for wastewater RO.
- Customize Antiscalant for Multiple Effect Evaporation (MEE).
- High-Temperature Antifoaming Agents for MEE.
- Bio-remediation for secondary treatment.

A Case Study on CETP

A CETP Plant in Western India having Capacity of treatment of 20-22 MLD of effluent. Effluent is generated mainly from Dyes, textile Industries, and specialty chemical industries. Effluent predominantly have colour due to dye industries along with oil, fine suspended solids which are contributing to COD and BOD.

Effluent treatment: Based on TDS Level

- Based on the TDS level effluent are segregated
- Low TDS Effluent – Bio-Chemical Treatment (10,000-15,000 ppm)
- High TDS Effluent – MEE Treatment (>1.0 Lac ppm)

Low TDS Effluent – Bio-Chemical Treatment

The design of the Low TDS Effluent treatment system intricately produced the synergetic effect of water treatment chemicals and tailor-made bio-cultures. The general layout of the water treatment system is described below:

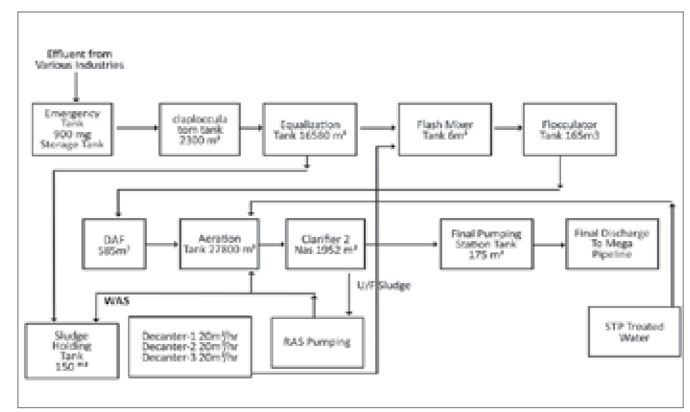


Fig. 1: Layout of the Low TDS effluent treatment system

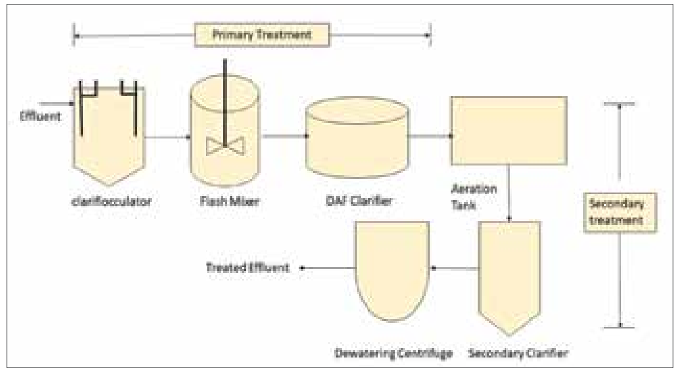


Fig. 2: Block Diagram of the CETP Plant

Components & Working of the CETP

- Clariflocculator- The clariflocculator facilitates the separation of the suspended and colloidal particles by using the principle of gravity. The addition of the anionic or cationic flocculants accelerates the rate of sedimentation.
- Flash Mixer- This stage involves the addition of the chemicals to foster the coagulation of the small particles remaining in water after the first step.
- Dissolved Air Flotation (DAF) Clarifier- This step is very crucial as it removes the suspended solids (TSS) from the wastewater stream by using an air-in-water solution.
- Aeration Tank- After the primary treatment of coagulants and flocculants at the previous clarifiers, the Aeration tank facilitates the advance wastewater treatment by targeting the COD and BOD load of the effluent. The Aeration tank was fed with the tailor-made bio-cultures to promote maximum COD/BOD reduction.
- Secondary Clarifier- the Secondary clarifier separates the MLSS Load, which is purged to the aeration tank system to maintain its MLSS.
- Dewatering Centrifuge- Sludge collected from primary and secondary system dewatered by High Speed horizontal solid bowl centrifuge /Decanter. Efficiency of this solid-liquid separation increased by the addition of High molecular weight Dewatering Polyelectrolyte.
- We optimized the chemicals as well as the biological system to achieve maximum reduction in pollutant load. The detail specifications are given below:

Observations & Results for the Bio-Chemical Treatment of Low TDS Effluent:

SR.	STAGES	PRODUCT	DOSES (PPM)
1	Primary Clarification-	Cationic coagulant	10
2	Primary Clarification-Clariflocculator	Anionic Flocculent	0.2
3	Primary Clarification-Flash Mixer (Before DAF)	Cationic Coagulant	5
4	Primary Clarification (DAF)	Anionic Flocculent	0.4
5	Dewatering – Centrifuge	Anionic Flocculent	50
6	Secondary Clarification	Cationic Coagulant	0.6
7	Aeration Tank	Customized Microbial Culture	<5.0

Table 1: Recommended Products and Dosages

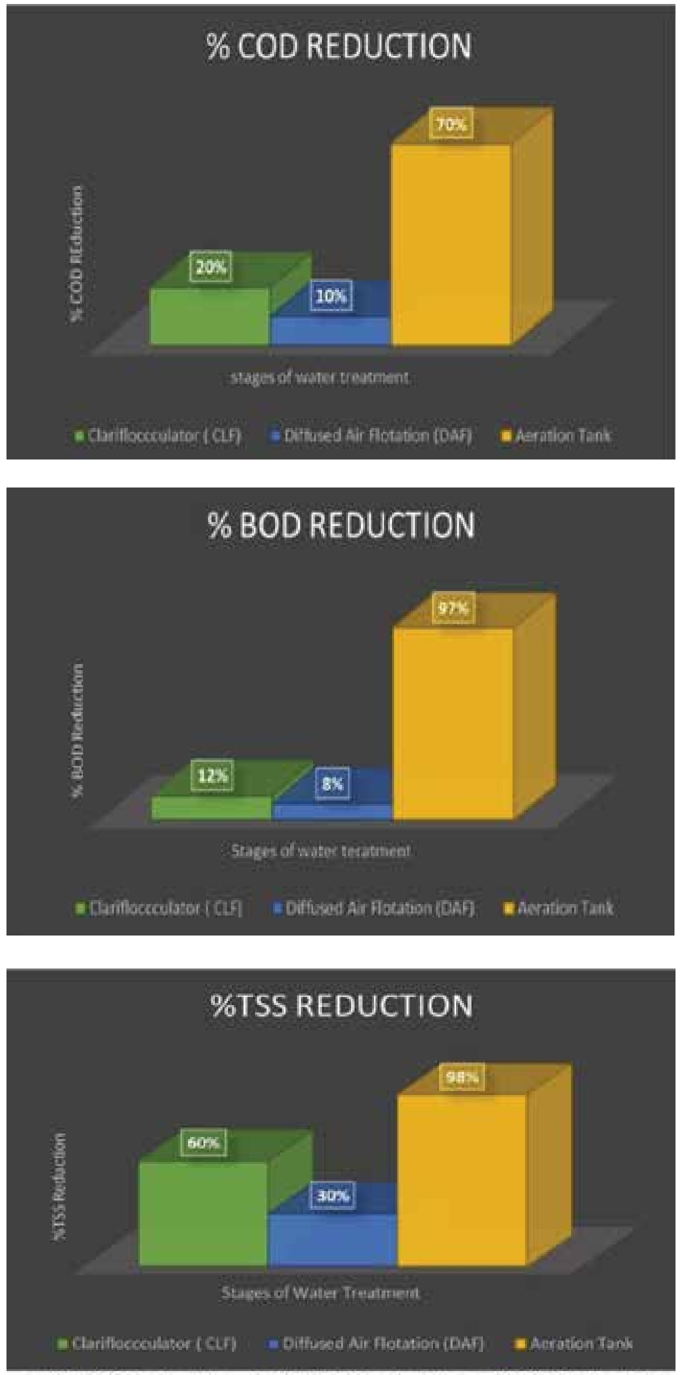
Table 2 and 3 indicates the characteristics of the effluent before and after treatment, and the total reduction of the pollutants load respectively.

Feed /Outlet Quality		
Parameter	Feed Quality	Outlet Quality
pH	6.50-7.50	7.0-8.0
COD (ppm)	1200-1800	300-400
BOD (ppm)	500-600	20-40
TDS (ppm)	10000-15000	10000-15000
TSS (ppm)	300-400	50-80

Table 2: Characteristics of the CETP effluent (Low TDS) before and after-treatment

Outlet Quality	Reduction Across CLF	Reduction Across DAF	Reduction Across Aeration
% COD Reduction	15 - 20 %	8-10%	65-70%
% BOD Reduction	10 - 12 %	5 -8 %	95-97 %
%TSS Reduction	50 - 60 %	25 -30%	96-98 %

Table 3: Stage wise reduction of the pollutants across the Primary and Secondary System



a. % COD Reduction, b. % BOD Reduction c. %TSS Reduction

Fig. 3 Comparison of % Pollutant reduction at different stages of the water treatment system

Conclusion

The higher TSS reduction at the primary treatment reduced the toxicity of the complex effluent and facilitated higher COD and BOD reduction at the secondary treatment. This synergetic effect enhanced the pollutant reduction rate and also increased the sustainability of the process.

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Mr. Sachin Shirke work with Chembond Water Technologies as Senior Manager, Water Treatment Division. He has Chemical Engineering background and have more than 15 years of work experience in chemical treatment of water and waste water across different industrial segments.

Advantage of Controlling Internal Corrosion in Crude Oil Pipe Lines



The aim of this article is to describe and analyze corrosion problems and their solutions in oil, gas, and refining industry. Corrosion phenomena and factors influencing them are discussed.

By V. Ramanathan

Briefing about Corrosion

Corrosion is an electrochemical phenomenon by which a metal returns to its natural state. Large amount of energy is put in during the extraction of metals from their ores which raises the metals to a Meta stable state with respect to their environment. Consequently, the metals have a strong thermodynamic tendency to return to the more stable oxide form.

Being an electro chemicals process, for corrosion to occur, a corrosion cell consisting of an anode, a cathode and an electrolyte must exist. At the anode, metal ions dissolve into the electrolyte (Water). As the metal ions go into solution at the anode, electrons are left behind, which migrate through the metal to the other points (Cathode), where the cathodic reaction takes place, i.e. the electron is consumed.

Cathodic Reactions:

1. $O_2 + 2H_2O + 4e \longrightarrow 4OH$ (natural aerated waters)
2. $2H + 2e \longrightarrow H_2$ (acidic PH)
3. $O_2 + 4H^+ + 4e \longrightarrow 2H_2O$(aerated acidic solution)
4. $Fe^{+3} + e \longrightarrow Fe^{+2}$ (acidic, turbulent conditions iron reducing bacteria)
5. $4H^2 + SO_4^{-2} \longrightarrow S^{-2} + 4H_2O$ (SRB attack)
6. $2H_2O + 2e \longrightarrow H_2 + 2OH$(natural waters)

The hydroxyl ions formed at the cathode combine with the ferrous cations.

$$Fe^{+2} + 2OH \longrightarrow Fe(OH)_2$$

Some Important Factors That Affect Corrosion:

- **pH:** The rate of corrosion is dependent on the pH. Generally corrosion is more severe in acidic pH as most protective metal oxide films are soluble in acidic or slightly alkaline water.
- **Oxygen and other dissolved gases:** Oxygen dissolved in the water is necessary for the cathodic reaction to take place. Some of the other gases that influence corrosion are:
- CO_2- forms H_2CO_3 and reduces the pH. sulphure

Fouling:

Fouling is the deposition of suspended matter, insoluble in water or in crude oil. They can be water borne or air borne or underneath. Some of the common foulants are:

- Dirt and silt
- Sand
- Corrosion products
- Natural organics
- Microbial matter

The particulate matter generally accumulates in the low velocity areas or in the areas where there is an abrupt change in the direction of flow or flow velocity.

Factors that affect fouling:

1. Water Characteristics: Water /crude oil containing suspended material will cause fouling. Similarly surface water or crude oil have greater fouling tendency, as the amount of suspended matter picked up by them is greater.

2. Temperature: Fouling tendency increases with increasing temperature. Heat transfer surfaces which are hotter than the cooling water accelerate fouling.

3. Velocity: Fouling is greater in areas of low velocity while it is less severe in areas of high velocity. Normal velocity is 3 to 5 feet/ second.

4. Microbial Growth: Microorganism can deposit on any surface. Certain bacteria like iron bacteria utilize corrosion products leading to voluminous deposits. Also, slime secreted by bacteria, act as binders and entrap material which normally would not have deposited.

5. Corrosion Products: Insoluble corrosion Products mixes with other foul ants like debris, DilbitsMicro, etc. and aggravates fouling. It also serves as a nutrient for iron bacteria & SRB/SOB/NB, promoting their growth.

The major problem microbes are:

1. Algae
2. Fungi
3. Bacteria[SRB/SOB/NB/IRB]

Algae: In case of crude oil transfer pipe line, algae may not play major role because direct sunlight is possible

Fungi: Fungal in crude oil pipe can play small limited role because it needs organic food for growth which is not available in pipe line, if it is wood it may grow. Fungi reproduce by forming spores. Spores can remain dormant for a long time and proliferate when conditions become favorable. In their dormant state they are harmless. Spores are generally resistant to most micro biocides and can present very difficult situation.

Bacteria: Many different species of bacteria are found in crude oil pipe line water systems. Control, therefore becomes extremely difficult as agents toxic to one species may have little or no effect on some other species. The commonly found bacteria [SRB/SOB/NB/IRB] in Crude oil systems which are detrimental to the system are:

1. Pseudomonas: These bacteria are notorious for the slime that they generate. The slime acts as a binding agent for dust and precipitation, thereby causing voluminous deposited gets deposited due to the binding action of the slime.

2. Sulphur Reducing Bacteria(SRB): These are anaerobic and generate the energy required for their growth by reducing sulphur to sulphides and in the process corrode iron.

$$4Fe + SO^{2-}_4 + 4H_2O \qquad FeS + 3Fe(OH)_2\neg + 2OH$$

This is the mechanism by which it directly corrodes iron. It also indirectly corrodes iron by the formation of H2S which attacks the metal.

3. Iron Bacteria: These utilise iron for their growth and create iron deposits as a byproduct of their metabolism.

$$4FeCO_3\neg + O_2 + 6H_2O \qquad 4Fe(OH)_3 + 4CO_2 + 81,000cal$$

To generate the energy requisite for their growth they must produce large quantities of ferric hydroxide. This gets entrained in the organism producing voluminous deposits

4. Nitrifying Bacteria: They are the nitrosamines and nitrobacter which generate energy by converting nitrogenous compounds like ammonia to nitricacid. Ammonia-NitrosomonasNitries – Nitrobacter Nitrates. The drop in pH due to the acid formed directly leads to corrosion and the presence of these organisms can be easily detected by the continual drop in pH of the circulating water.

Corrosion Inhibition

Corrosion Inhibitors prevent the metal from reverting to its natural oxide state. Depending on the corrosion reaction it controls, a corrosion inhibitor can be anodic, cathodic or general. Anodic inhibitors form thin protective film along the anode. The film is initiated at the anodes and eventually may cover the entire metal surface. Anodic inhibitors in low concentrations are dangerous because the entire corrosion potential will occur at the unprotected anodic sites leading to severe pitting

Cathodic inhibitors form a thin protective file on the cathode. It restricts the access of dissolved oxygen to the metal surface. Low concentration of these inhibitors lead to general attack and not pitting as the corrosion rate is increased in direct proportion to the increase in the cathodic areas.

Corrosion inhibitors which protect the metal surface by filming all metal surfaces anodic or cathodic are called general or filming

type Corrosion inhibitors [Ameztreat-900].
Of the lot, Ameztreat-900 [Formulated combination of all type] is the oldest and best known corrosion inhibitor available even today. It is highly effective in crude oil pipe protection and is an environmental friendly product however, its discharge in high concentration necessitates a fresh look in treating it before letting into environment.
In the early forties it was found that the inhibitive action of two corrosion inhibitors used together was far greater than the sum of the individual action. This is the so called synergistic effect.

Further, it became evident that the combination of cathodic and anodic corrosion inhibitors gave best protection at economical use levels,

Anodic	Cathodic	General
Chromates	Polyphoshates	Soluble oils an
Orthophospates	Metal cations	Organic like
Nitrites	Bicarbonates	azoles, amine
Silicates	Organic Phosphates	Ameztreat-900

Orthophosphate are excellent anodic inhibitors, but are associated with the problem of calcium orthophosphate sludging. They should be properly conditioned with specific antifoulants to prevent their deposition. The same should be taken care of when using polyphosphates that revert care of when using polyphosphates which revert to orthophosphate under cooling water condition. Organophosphonates and polymers are a new class of compounds which are not corrosion inhibitors by themselves at use levels, but exhibit excellent synergism with other corrosion inhibitors to give good corrosion protection. They have excellent thermal and hydrolytic stability and do not revert to orthophosphate.

Chromate	Polyphosphate
Zinc	Polyphosphate
Chromate	Orthophosphate
Zinc	Organophosphonate
Polyphosphate	Silicate
Polyphosphate	Polymer
Zinc	Phosphonate-Polymer
Zinc	Polyphosphate-Silicate
Chromate	Zinc-Polyphosphate
Chromate	Zinc-Phosphonate

Table 1[Aqua media based Ameztreat]

Ingredient
Fatty acid, tall oil, polymers, ethoxylated
Alkyl pyridine benzyl chloride quaternary
Nonylphenol, branched, ethoxylated
2-Ethylhexanol, ethoxylated, phosphated potassium salt
Phosphate esterAmines, tallow alkyl, ethoxylated
Cocobenzyldimethylammonium chlorideEthanediol

For good corrosion protection, the pretreatment is absolutely necessary. Corrosion inhibitor at 2-4 times their normal dosage is applied over the first few days. This ensures the formation of a durable passivating film on the metal surfaces rapidly. Pretreatment should also be instituted after any system upsets, pH excursions, corrosive contaminants and prolonged low inhibitor levels.

Microbial Control:

Chemicals that kill microorganisms are termed as biocides. It is difficult to kill all the organisms in the crude oil system. What is best achieved is the maximum killing and control of growth. The efficacy of a biocide depends upon the nature and amount of pollutants such as hydrocarbons, pH, temperature and other nutrients such as orthophosphates present. Listed below are some of the well-known biocides.

Methylene BIsthiocyanate (MBT) & DBNPA: [Ameztreat-901]

This is a blend of oxidizing and non-oxidising biocide and an enzyme. It inhibits the cytochrome system. Microorganisms, therefore, are unable to build resistance to it. It is extremely effective against anaerobic bacteria, like SRB/NRB/IRB. MBT/DBNPA should not be used above a pH of 8 since it hydrolyses above that pH. Also, MBT is degraded to nontoxic products in the cooling water and stripped.

These are some of the commonly used biocides and many other fancy and specific biocides are available in the market. It is ineffective and expensive to add biocide haphazardly.

The selection of a proper biocide is confined to three factors:

It must be effective in inhibiting almost all microbial activity and must be economical. This is accomplished by using two biocides, one which is highly effective at low concentrations and is usually expensive and one with lower toxicity, but which is usually cheaper. The third factor to be considered is the disposal problem. Generally a slug dose at a frequency of once in 7 to 15 days is usually sufficient, but in severe cases the frequency and dose levels may have to be increased and decided-upon by expert.

The effectiveness of biocides is enhanced by the use of BIODISPERSTS. These loosen microbial deposits which can then be flushed a way. They also expose new layers of microbial slime or algae to the attack of biocides. They increase the penetrating power of active ingredients of biocides by exposing the underlying microbial deposits which would have otherwise been covered and sheltered. It is always preferable to select microbial treatment programs after analyzing the crude oil and slime samples to ascertain the type of organisms present.

Our Treatment Program for Managing Corrosion in the Crude Oil Transferring Pipe Lines

Method of our Approach

1) Pigging & Cleaning
2) Passivation
3) Regular Treatment

Pigging & Cleaning: Initially before starting the Treatment program, all the pipeline is to be cleaned thoroughly by using pigging equipment [Magnetic Flux leakage] along with one dose of Ameztreat 901 (Micro biocide) 50ppm based on holding capacity of pipeline 1M lengh*1.2M dia which travels throughout the length of total stretch. During this process, the entire pipeline gets cleaned, all corrosion product, Dillbits any salinity and bacteria (SRB) are thoroughly cleaned.

It becomes ready for getting passivized.

Quantity to be used for cleaning each line is calculated below

Passivation layer formation: Once the pigging & cleaning is over, passivizing the entire pipe line with corrosion inhibitor Ameztreat 900 @dose of 50ppm on hold up of 1M*1.2M, have to be applied upon by using MFL equipment to propel the liquids throughout the stretch of pipe required for passivizing entire system.

Regular Treatment: Once the cleaning & passivation is completed throughout, then we can start the regular refreshing dosage of both Ameztreat-900 &Ameztreat 901 @2- 3ppm based on quantity of flow [crude oil], it will act as a regular corrosion protective dosage and controlling the corrosion environment like water, acid, CO2, H2S gas formation and also bacteria like SRB, NRB, SOB, etc. thereby controlling entire corrosion rate within norms of less than 3.0mpy always. It could be monitored every month once by putting corrosion coupon in lime.

Whatever cost of treatment incurred in protecting pipelines by chemical mean is highly justifiable looking into the severity and loss due to corrosion occurred to the pipe line maintaining industries in various account, just for the reference and ready reckoned, we hereby give some established fact and case studies done already by pipe line industries.

Summary Of Costs Due To Corrosion Failures:

A summary of the average annual cost for natural gas (NG) and hazardous liquid (HL) transmission pipeline accidents is given in table 9. The fatality, injury, and "added legal" costs are all estimates based on discussions with industry experts. For these costs, high and low estimates are provided. The cost of hazardous liquid spills or natural gas leaks varies depending on the severity of the leak and the repair method selected. (14) Table 10 provides a range of costs for repair options. For estimating the cost of non-reportable leaks and spills, the pipe replacement costs are not utilized since this would place the accident in a reportable category (greater than $50,000).

In addition, there is a clean-up cost associated with the hazardous liquid spills. Because of the range for these estimates, the total annual cost of corrosion-related accidents (including non-reportable leaks and spills) ranges from $471 million to $875 million.

	DESCRIPTION	LOW ESTIMATE ($ x thousand)	HIGH ESTIMATE ($ x thousand)
Fatalities	One fatality per year (NG and HL combined) @ $1,000,000 to $4,000,000 per occurrence	1,000	4,000
Injuries	One injury per year (NG and HL combined) @ $500,000 to $1,000,000 per occurrence	500	1,000
Added Legal	Legal issues and liability (civil and punitive) @ $100,000,000 to $200,000,000 per fatality and injury (2)	200,000	200,000
Property Damage – HL	45 HL accidents/year @ $192,300 per occurrence	8,654	8,654
Property Damage – NG	19 NG accidents/year @ $169,500 per occurrence	3,220	3,220
Loss of Throughput – HL	45 HL accidents/year @ $1.15 million to $2.3 million per occurrence	51,750	103,500
Loss of Throughput – NG	19 NG accidents/year @ $287,000 to $574,000 per Occurrence	5,453	10,906
Non-Reportable HL Spills	1,600 oil spills/year (HL) of less than 50 barrels @ $25,000 to $40,000 per occurrence	40,000	64,000
Non-Reportable NG Leaks	8,000 leaks/year (NG) @ $20,000 to $35,000 per Occurrence	160,000	280,000
TOTAL ANNUAL COST OF CORROSION-RELATED PIPELINE FAILURES		$470,577	$875,280

Table 9. Summary of annual cost for corrosion-related transmission pipeline failures.

NG – NATURAL GAS; HL – HAZARDOUS LIQUID

	COMPOSITE SLEEVE	STEEL SLEEVE	10-FT PIPE REPLACEMENT
Material Cost	$1,000	$1,600	$500
Labor Cost	$11,000	$16,500	$30,000
Gas Loss*	$0	$0	$19,000
Other Expenses**	$7,000	$7,000	$20,000
TOTAL REPAIR COST	**$19,000**	**$25,100**	**$69,500**

**Gas loss calculated from 16-km section at 5,520 kPag (10-mi section at 800 psig). **Surveys, permits, inspection services, ROW-related expenses, etc.*

TABLE 10. Cost comparison of composite sleeve, full-encirclement steel sleeve, and pipe replacement repair techniques.

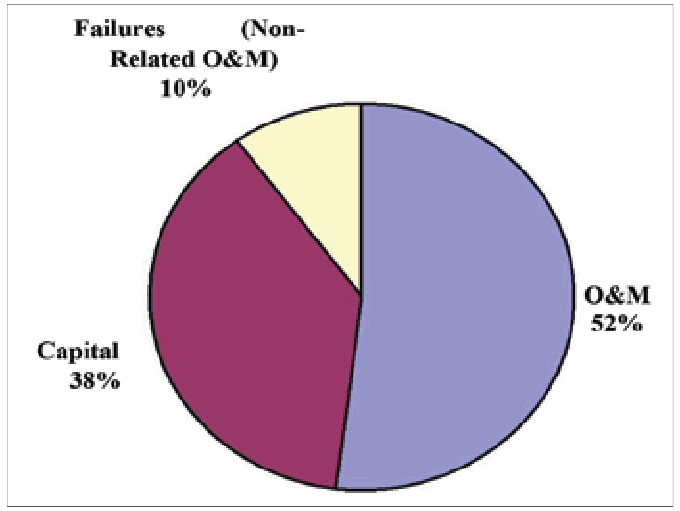


Figure 16. Percentage breakdown of the total cost of corrosion for the transmission pipeline sector.

Total Cost of Corrosion

The total cost of corrosion is determined by the cost of capital, operations and maintenance (O&M), and the cost of failures (non-related O&M costs). The pipeline rehabilitation and replacement costs are included in the capital costs. The costs presented in table 11 summarize these costs for typical pipeline operations in the 1990s. The total costs are estimated to be $5.40 billion to $8.56 billion annually. Figure 16 gives the percentage breakdown of the total cost of corrosion for the transmission pipeline sector. Operation and maintenance costs are 52 percent of the total costs associated with corrosion.

	LOW ESTIMATE	HIGH ESTIMATE	AVERAGE	
	($ x million)	($ x million)	($ x million)	(percent)
Cost of Capital	2,500	2,840	2,670	38
Operations and Maintenance (O&M)	2,420	4,840	3,630	52
Cost of Failures (Non-Related O&M)*	471	471	673	10
TOTAL COST DUE TO CORROSION	$5,391	$8,555	$6,973	100%

**Non-Related O&M costs include indirect costs associated with fatalities, injuries, loss of throughput, and legal expenses (see table 9).*
Table 11. Summary of the total cost of corrosion in the transmission pipeline sector.

Increase consciousness of corrosion costs and potential savings.	Increase consciousness of corrosion costs and potential savings.
Change perception that nothing can be done about corrosion.	Corrosion prevention practices are well defined and generally known in the pipeline sector.
Advance design practices for better corrosion management.	Corrosion prevention design practices for pipelines are generally well understood. Computer models for cathodic protection design of complex systems are recently becoming available.
Change technical practices to realize corrosion cost-savings.	Technical practices will have to change based on new regulations involving increased pipeline inspection. Incorporating these inspection methods into the current corrosion prevention practices in a cost-effective manner will be critical to operators.
Change policies and management practices to realize corrosion cost-savings.	The key for management will be to incorporate inspection strategies into current corrosion prevention strategies while continuing to improve corrosion prevention.
Advance life prediction and performance assessment methods.	cost-effective pipeline integrity management. These models are not always available and are, in general, specific to individual pipeline conditions. Corrosion growth and life- rediction models are required for establishing inspection frequency and prioritizing corrosion prevention maintenance.
Advance technology (research, development, and implementation).	Technology advancements needed include improved inspection techniques (better reliability, resolution, crack detection).
Improve education and training for corrosion control.	New federal regulations require training of corrosion technicians. NACE International (National Association of Corrosion Engineers) has recently updated and is now providing courses and certification especially for cathodic protection technicians.

Recommendations & Implementation Strategy

Corrosion prediction models need to be developed in order to more accurately determine inspection intervals and to prioritize the most effective corrosion prevention strategies. Development of new and improved inspection techniques is required to expand the capabilities of in-line inspection of flaws that cannot be currently detected and to improve resolution for existing tools.

Conclusion

The program for protecting the crude oil transferring pipe line by chemical means also is highly need of the hour throughout the world wherever excavation and extraction of crude sub vent

About the Authors

Mr. V. Ramanathan is the Managing Director of Sri Sakthi Chemicals Pvt. Ltd. He is an MSc in Industrial Chemistry Specialization in electro Chemistry from CECRI and has an experience of 30 years in the water treatment and allied specialty field. He has published 5 papers in corrosion scaling and microbiological control in relevant journals. He has worked in many kinds of industries as supplier of water treatment chemicals.

Effluent Treatment Process in the Chemical Industry

Safe handling of chemicals for the treatment process of the Effluent Treatment Plant and treating hazardous substances in the wastewater such as Hexavalent chromium and Cyanide is crucial.

By A. Yudhistra Kumar

Safe chemical handling practice and procedures should be followed during the handling of the chemicals for the treatment of effluent treatment process in the Chemical industry. It is very much necessary to read the warning of the labels of the chemical used in the treatment process and also should refer the Master Safety Data sheet (MSDS) before using the chemical for the treatment process. Do not store together or mix incompatible chemicals together such as HCL/sulphuric acid with sodium hydroxide. It is necessary to do a compatible study before handling the chemicals. If an ineffective chemical is used in the treatment process, then it can have a negative effect on the treatment process thus, the efficiency of degrading the inorganic constituents present in the wastewater can be reduced. All the chemicals, which are used for the treatment purpose should be kept on the pallets and stored away from the sunlight and kept at room temperature in a closed room where there is no moisture. All the chemicals should be labelled for proper identification. The people handling the chemicals for the treatment process should be trained to handle the chemicals and the usage of such chemicals should have a record book, consumption on daily basis should be recorded and stock should be verified frequently. Whenever it is necessary the required chemicals can be procured before the existing stock of the chemicals gets exhausted, so that we have enough chemicals for using in the process of the Effluent Treatment Plant (ETP).

Handling Procedure for Chemicals

The operator should wear proper Personal Protective Equipment (PPE) for handling the chemicals in the ETP. The operator should have the knowledge of using the appropriate chemicals for the treatment process. For example a person is handling sodium hydroxide/sulphuric acid for the treatment process, then in that scenario he should use suitable kind of gloves (Nitrile Gloves), which is recommended by European union such as EN AJKL with Accepted quality Level (AQL) - 3 nitrile gloves, where K and L of nitrile gloves stands for resistance to sodium hydroxide 40% and sulphuric acid of 96% concentration and AQL level -3, which refers to the pin hole defects of 0.5% defects from the random sampling. It is important to use chemical splash proof goggles, while handling the acids to protect the eyes. The operator should wear organic mask, while handling the acids, so that we can protect from fumes of the acids, which are used in treatment process of the ETP. The operator should wear safety shoes, so that any spillages happen, while handling the chemicals should not affect the legs.

Handling of the Spillages of the Acids

Spillages of Acids, which is used in the treatment process of the ETP should be handled properly and utmost care should be taken while handling the chemicals otherwise it will contaminate the soil area near the effluent treatment process, thus polluting the environment and other the thing is that there is a risk of injury for the operator, who is operating the ETP. In case of spillage of the acids, immediately the operator should sprinkle the dried river sand on the acid contaminated area, as the dried river sand contains silica, it observes the acid vapours and thus fumes from the acids will be restricted. Finally clean and sweep the area.

Hexavalent Chromium uses, its Health Eeffects on Human Being

Chromium pigment is used in dyes, paints, inks and plastics. Chrome act as an anti-corrosive agent to the paints and primers. It is also used in the electroplating industry. Exposure of the chrome concentration to the employees from the above units will cause lung cancer to the employees, who breathe the hexavalent chromium at high level. Prolonged exposure can result in nose bleeds. If the damage is severe, the nasal spectrum (wall separating the nasal passage) develops a hole in it. Long term exposure can cause asthma such as wheezing and shortness of breath. People exposed to the hexavalent chromium can be affect in the skin called allergic contact dermatitis. This occurs, while handling any solid or liquid, which consist of hexavalent chromium.

The reaction perception methods find wide application in the treatment of hexavalent chromium. The economical and removal efficiency in the process is quite high. Besides it is possible to reuse the treated water. There are three steps involved in the treatment process. First is the adjustment of pH and other is reduction and precipitation. The chrome wastewater containing the hexavalent chrome, in case of low pH is called chromic acid. While in case of high pH it is chromium hydroxide, in that scenario it will be decreased to 2 pH by addition of sulphuric acid, thus resulting the pH of chromium waste. Then the reduced agent sodium meta bi sulphide (SMBS) will be added, so that the colour of orange will turn brown (Hexavelent Chrome) and will change to blue or green in colour (Trivalent chrome), during the process pH will be raised from 10 to 10.5 by addition of sodium hydroxide (Tabel.1). In order to settle the sludge alum is added during the treatment process and finally sodium hypochlorite is added in order to settle in the lamella filter and the treated water is let out In case of higher concentration of hexavalent chromium, 25 times of dilution of the concentration should be performed. For example, if the hexavalent chromium concentration is 250 grams/L, it should be diluted to 25 grams/L and it should be treated as above.

Note: One kilogram of hexavalent chromium requires ten to fourteen kilograms of SMBS to convert hexavalent to trivalent chromium.

Cyanide uses, its health effects on human being and on the Environment

Utilizing cyanide compounds in mining and chemical industry is one of the most important environmental issues due to the acute toxic properties of many cyanide compounds to humans and aquatic life. Cyanide tends to react readily with most other chemical elements, producing a wide variety of toxic, cyanide related compounds. Cyanides are highly toxic; in short term exposure it can cause the following health effects: rapid breading, tremors and other neurological effects; long term exposure can cause weight loss, thyroid effects and nerve damage. Therefore, cyanide must be destroyed or removed from wastewater prior to discharge. Stricter environmental regulations for the discharge of cyanides make it necessary to develop processes for their removal from the wastewater. Several techniques are used for treating cyanide. Cyanide concentrations more than 0.07 mg/L, are intensely harmful to aquatics. A common method for the oxidation of cyanide wastewater is chlorination at high pH to form CNO-, CO2, N2 and NH4. The methods to degrade cyanide solutions can be divided into three major groups: natural, chemical and biological degradation. Chemical Treatment method has been used for treating the cyanide to cyanate.

Compounds of cyanides present in water can be generally classified into total cyanide, complex cyanide and free cyanide. These aqueous cyanide compounds exist as simple and complex cyanides, cyanates and nitriles. The most toxic form of cyanide is free cyanide, which exists either as cyanide anion or as hydrogen cyanide (HCN) depending on solution pH. HCN is predominant in aqueous systems at pH below 8.5 and can be readily volatilised. At higher pH values, the free cyanide is mainly in form of the cyanide anion. Aqueous cyanides form complexes with metal ions present in industrial wastewaters. These metallo-cyanide complexes exhibit different chemical and biological stabilities.

Sr. No	Chemical Name and its concentration	Tank capacity (Ltrs)	Dosing Pump capacity (Ltrs/hr)	Percentage of Dosing performed	Chemical added (Ltrs/kg)
01	Sulphuric acid (10 %)	200	500	100	20
02	SMBS (10 %)	400	500	300	40
03	Sodium Hydroxide (10 %)	1000	500	100	100
04	Alum (5%)	200	10	100	10
05	Sodium hypo chlorite (10 %)	600	500	14	102

Table 1: Chemical concentrations used while treating the Hexavalent Chromium concentration in the wastewater

Complexes of cyanide with cobalt, iron, silver and gold are strong acid dissociable (SAD). Both forms of complexes dissociate and release free cyanide. The stability of these complexes depends on several factors such as pH, light intensity, water temperature and total dissolved solids.

Cyanide is also produced naturally in the environment by various bacteria, algae, fungi and numerous species of plants including beans (chickpeas and lima), fruits (seeds and pits of apple, cherry, pear, apricot, peach and plum), almond and cashew nuts, vegetables of the cabbage family, grains (alfalfa and sorghum), roots (cassava, potato, radish and turnip), white clover and young bamboo shoots. Incomplete combustion during forest fires is believed to be a major environmental source of cyanide, and incomplete combustion of articles containing nylon produces cyanide through depolymerization.

Once released in the environment, the reactivity of cyanide provides numerous pathways for its degradation and attenuation, so cyanide should treated in a more effective way. Different types of cyanide, which has different molecular weight, so oxidation rates are high

The molecular weight with respect to cyanide is high, so the oxidation happens during the higher RPM of 300 in the treatment process. Cyanide is bivalent and monovalent in nature. Silver cyanide is monovalent whose molecular weight of silver is 107, carbon is 12 and nitrogen is 14, so total molecular weight of silver cyanide is 133. Another monovalent ion is sodium cyanide, where sodium molecular weight is 22, carbon, 12 and nitrogen is 14, so total sodium cyanide molecular weight is 48. In case of Bivalent cyanide such as copper cyanide, the molecular weight of copper is 63, carbon is 24 and nitrogen is 28, so molecular weight of copper cyanide is 115, which is higher in molecular weight compared to other cyanides molecular weight, which is given above. Cadmium cyanide, which is a bivalent, has the highest among all the cyanides, where cadmium molecular weight is 112, carbon is 24 and nitrogen is 28, so molecular weight of cadmium cyanide is 164

Treatment of cyanide using the chemical process

From the effluent collection tank, the cyanide rinse is pumped to cyanide reaction tank. The pH of cyanide wastewater is raised to 9 to 12 by addition sodium hydroxide. The addition of sodium hydroxide is controlled by a pH controller. It should always maintain a pH of 12, then the sodium hypochlorite is mixed with a retention time of 4 hours for the oxidation process, during the period agitation RPM should be 300. Performing the addition with the chlorine, oxygen reduction potential of 200 mw should maintain cautiously with a pH of 11 to 12. If the cyanide is acidified during the addition it leads of the poisonous gas such as hydrogen cyanate gas. After 4 hours of retention cyanide is converted to cyanate with end product of carbon dioxide and nitrogen gas. In that scenario the cyanate is pumped to the flash mixture with alum and then to the lamella filter. The treated water were within the standards (Table 2)

In case the concentration of the cyanide is high such as 100 gram/litre, then it should be converted to 1 gram/litre, where 100 times of dilution is performed. Three times of the chemicals are needed, 100 mg of cyanide, which requires 300 mg of chlorine for the treatment process.

S.No	Government Agencies	Limits of Cyanide
1	CPCB	0.2 mg/l
2	EPA	
	Aquatic Biota	50 ppb
	Drinking water	200 ppb
3	Mixico	0.2 mg/l

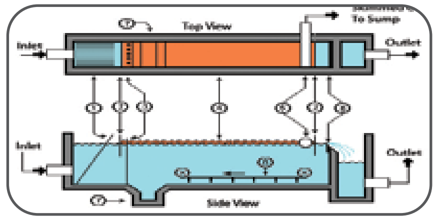
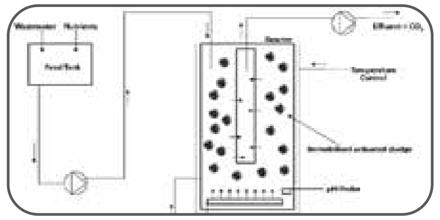
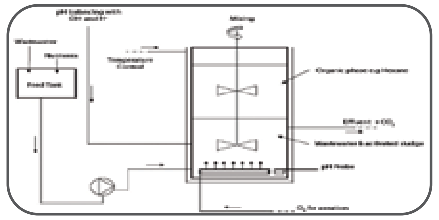
Table 2: Limits of cyanide as per the Central pollution control board, Environmental protection agency and Mexican government

The chromium and cyanide water to be segregated properly in the form of separate streams. The chromium water is acidic in nature and if it is mixed with the cyanide water, which is alkaline in nature, then it will lead to the poisonous hydrogen cyanide gas, so mixing of the two chemicals of chromium and cyanide to be avoided; hence these two effluents are to be segregated and kept separately.

About the Authors

A. Yudhistra Kumar presently is working as EHS manager at Lake Chemicals Pvt ltd at Bangalore. Having more than ten years of experience in the field of Environment and Safety aspects after completing Ph.D in Environmental sciences.

Waste Water Treatment in Chemical Industries: The Concept and Current Technologies

The article highlights the Concept and Current industrial wastewater treatment technologies in chemical industry. Read on…

By Mohamed Osman Awaleh & Youssouf Djibril Soubaneh

The world's chemical industries face formidable environmental regulatory challenges in treating their wastewater effluents. The present work aims at highlighting the various industrial wastewater treatment technologies currently available including physico-chemical and biological processes as well as constructed wetland and conventional or advanced oxidation processes. Activated carbon prepared from low cost material, Agricultural by-product materials or modified natural polymers, which is considerably efficient for removal of direct dyes from wastewater, is also discussed. Combinations of anaerobic and aerobic treatment processes are found to be efficient in the removal of soluble biodegradable organic pollutants. The use of membrane in final stage of industrial wastewater treatments is increasing. The chemical oxidation techniques to treat wastewater, classical chemical treatment and advanced oxidation processes, is discussed.

Introduction

Even though it appears to be in plentiful supply on the earth's surface, water is a rare and precious commodity, and only an infinitesimal part of the earth's water reserves (approximately 0.03%) constitutes the water resource which is available for human activities. The growth of the world's population and industry has given rise to a constantly growing demand for water in proportion to the supply available, which remains constant. Thus, it is necessary to minimize its consumption and it is also necessary to return it back to the environment with the minimum contamination load because of the limited capacity of selfpurification, hence the importance of wastewater treatment process [1].

During the last two decades large scale environmental initiatives have taken place in Europe and the United States, these have resulted in strict environmental regulations on the industrial emissions for the chemical industry. It has been necessary to invest in cleaner technologies and in treatments that are more effective. On the other hand, numerous chemical companies have installed effluent treatment systems to meet the recently elaborated regulations of the country in which they are settled or to meet the regulations of the countries with which they trade.

The chemical industry comprises the companies that produce industrial chemicals. Basic chemicals or "commodity chemicals" are a broad chemical category including pharmaceutical products, polymers, bulk petrochemicals and intermediates, other derivatives and basic industrials, inorganic/organic chemicals, and fertilizers. The chemical industry is of importance in terms of its impact on the environment.

Chemical industrial wastewaters usually contain organic and inorganic matter in varying concentrations. Many materials in the chemical industry are toxic, mutagenic, carcinogenic or simply almost non-biodegradable. This means that the production wastewater also contains a wide range of substances that cannot be easily degraded. For instance, surfactant and petroleum hydrocarbons, among others chemical products that are being used in chemical industry reduce performance efficiency of many treatment unit operations [2].

The purpose of this review is to discuss the current wastewater treatment technologies in chemical industry. Because of the specificity of their waste waters, the chemical industry are required either improving the existing waste water treatment processes or

developing combinations of various processes. This enables one to emerge with feasible treatment schemes targeting treatment of high strength wastewater.

Technologies To Treat Chemical Industry Effluents

In terms of wastewater treatment there are four classifications of treatment. Preliminary treatment involves the removal of large particles as well as solids found in the wastewater. The second classification is primary treatment, which involves the removal of organic and inorganic solids by means of a physical process, and the effluent produced is termed primary effluent. The third treatment is called secondary treatment; this is where suspended and residual organics and compounds are broken down. Secondary treatment involves biological (bacterial) degradation of undesired products. The fourth is tertiary treatment, normally a chemical process and very often including a residual disinfection.

Physico-Chemical Treatment

Oil –Water Separator–Treatment of oily effluent: Oil and grease (O&G) is a common pollutant in a wide range of chemical industries. Oil refineries, petrochemical plant, chemical plant, textile and food processing industries report high levels of oil and grease in their effluents (with an Oil and grease concentration up to 200,000 mg/l) [3,4].

Regulations that govern the allowable discharge of oil and grease into municipal treatment plants and surface waters are becoming increasingly stringent. New facilities are also subject to more stringent discharge limits than existing sources. For example, existing sources discharging produced water are required in the US to limit O&G levels to less than 48 mg/l as compared to new facilities which have to comply with a limit of 29 mg/l [3,4].

On the other hand, Oil and grease in wastewater can exist in several forms: free, dispersed or emulsified. The differences are based primarily on size. In an oil–water mixture, free oil is characterized with droplet sizes greater than 150 mm in size, dispersed oil has a size range of 20–150 mm and emulsified oil has droplets typically less than 20 mm. Oil and grease concentrations in wastewater as measured by the recommended test procedures of the US Environmental Protection Agency do not determine the presence of specific compounds, but groups of compounds based on their extractability by a particular solvent. Solvents that are commonly used are freon and hexane. Thus, the term "oil and grease" is fairly broad; it could include animal and vegetable source oils, fatty acids, petroleum hydrocarbons, surfactants, phenolic compounds, napthenic acids, etc. [3,4].

Conventional approaches to treating oily wastewaters have included gravity separation and skimming, dissolved air flotation, de-emulsification, coagulation and flocculation. Gravity separation followed by skimming is effective in removing free oil from wastewater. Oil – water separators such as the API separator and its variations have found widespread acceptance as an effective, low cost, primary treatment step.

The API oil – water separator is designed to separate the oil and suspended solids from their wastewater effluents. The name is derived from the fact that such separators are designed according to standards published by the American Petroleum Institute (Figure 1).

The API separator, however, is not effective in removing smaller oil droplets and emulsions. Oil that adheres to the surface of solid particles can be effectively removed by sedimentation in a primary clarifier. Dissolved air flotation (DAF) uses air to

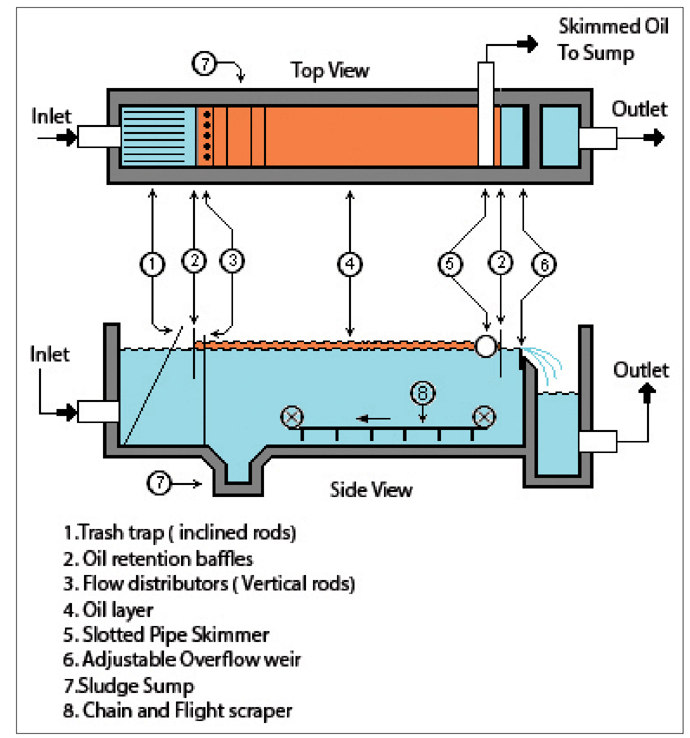


Figure 1: Conceptual Diagram of a gravimetric API separator.

increase the buoyancy of smaller oil droplets and enhance separation. Emulsified oil in the DAF influent is removed by de-emulsification with chemicals, thermal energy or both. DAF units typically employ chemicals to promote coagulation and increase flock size to facilitate separation.

Emulsified oil in wastewater is usually pre-treated chemically to destabilize the emulsion followed by gravity separation. The wastewater is heated to reduce viscosity, accentuate density differences and weaken the interfacial films stabilizing the oil phase.

This is followed by acidification and addition of cationic polymer/ alum to neutralize negative charge on oil droplets, followed by raising the pH to the alkaline region to induce flock formation of the inorganic salt. The resulting flock with the adsorbed oil is then separated, followed by sludge thickening and sludge dewatering.

Coagulation–flocculation: Most wastewater treatment plant includes sedimentation in their process. The sedimentation also called clarification is a treatment process in which the velocity of the water is lowered below the suspension velocity and the suspended particles settle out of the water due to gravity. Settled solids are removed as sludge, and floating solids are removed as scum. Wastewater leaves the sedimentation tank over an effluent weir to the next step of treatment. The efficiency or performance of the process is controlled by: retention time, temperature, tank design, and condition of the equipment. However, without coagulation/flocculation, sedimentation can remove only coarse suspended matter which will settle rapidly out of the water without the addition of chemicals. This type of sedimentation typically takes place in a reservoir, sedimentation or clarification tank, at the beginning of the treatment process.

Coagulation-flocculation consists on the addition on the clarification tanks of chemical products that accelerate the sedimentation (coagulants). The coagulants are inorganic or organic compounds such as Aluminium sulphate, Aluminium Hydroxide chloride or high molecular weight cationic polymer. The purpose of the addition of coagulant is to remove almost 90% of the suspended solids from the wastewater at this stage in the treatment process.

Adsorption techniques to treat wastewater: Adsorption is a natural process by which molecules of a dissolved compound collect on and adhere to the surface of an adsorbent solid. Adsorption occurs when the attractive forces at the carbon surface overcome the attractive forces of the liquid.

Granular activated carbon is a particularly good adsorbent medium due to its high surface area to volume ratio. One gram of a typical commercial activated carbon will have a surface area equivalent to 1,000 square meters.

Granular activated carbon: The pollution of water resources due to the indiscriminate disposal of heavy metals has been causing worldwide concern for the last few decades. It is well known that some metals can have toxic or harmful effects on many forms of life. Metals, which are significantly toxic to human beings and ecological environments, include chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), manganese (Mn), cadmium (Cd), nickel (Ni), zinc (Zn) and iron (Fe), etc. This problem has received considerable amount of attention in recent years. One primarily concern is that marine animals which can readily absorb those heavy metals in wastewater and directly enter the human food chains present a high health risk to consumers.

Wastewater from many industries such as metallurgical, tannery, chemical manufacturing, mining, battery manufacturing industries, etc. contains one or more of these toxic heavy metals. Industries carries out operations like electroplating, metal/surface finishing and solid-state wafer processing, generate wastewater contaminated with hazardous heavy metals. The concentrations of some of the toxic metals like Cr, Hg, Pb, As, etc. are higher than permissible discharge levels in these effluents. It, therefore, becomes necessary to remove these heavy metals from these wastewaters by an appropriate treatment before releasing them into the environment.

In view of the toxicity and in order to meet regulatory safe discharge standards, it is essential to remove heavy metals from wastewaters/ effluents before it is released into the environment. Conventional methods for the removal of heavy metals include precipitation, coagulation/flocculation, complexation/ sequestration.

Application of above-mentioned methods becomes economically unviable for the removal of heavy metals at lower concentrations. Adsorptive treatment using non-conventional adsorbents, such as agricultural and industrial solids wastes, have been used for the removal of heavy metals [5–7]. A number of other materials have also been used to remove heavy metals from wastewater, such as peat, wool, silk, and water hyacinth. Many papers have appeared on preparation of activated carbon from cheaper and readily available materials [6,7].

Fixed bio film reactor: The fixed bio film reactor is a trickling filter that consists of a bed of highly permeable media on whose surface a mixed population of microorganisms is developed as a slime layer. The word "filter" in this case is not correctly used for there is no straining or filtering action involved. Passage of wastewater through the filter causes the development of a gelatinous coating of bacteria, protozoa and other organisms on the media. With time, the thickness of the slime layer increases preventing oxygen from penetrating the full depth of the slime layer. In the absence of oxygen, anaerobic decomposition becomes active near the surface of the media. The continual increase in the thickness of the slime layer, the production of anaerobic end products next to the media surface, and the maintenance of a hydraulic load to the filter, eventually causes sloughing of the slime layer to start to form. This cycle is continuously repeated throughout the operation of a trickling filter. For economy and to prevent clogging of the distribution nozzles, trickling filters should be preceded by primary sedimentation tanks equipped with scum collecting devices.

Primary treatment ahead of trickling filters makes available the full capacity of the trickling filter for use in the conversion of non-settle able, colloidal and dissolved solids to living microscopic organisms and stable organic matter temporarily attached to the filter medium and to inorganic matter temporarily attached to the filter medium and to inorganic matter carried off with the effluent. The attached material intermittently sloughs off and is carried away in the filter effluent. For this reason, trickling filters should be followed by secondary sedimentation tanks to remove these sloughed solids and to produce a relatively clear effluent.

Due to its simple design, in actual operation the trickling filter is one of the most trouble-free types of secondary treatment processes. It requires much less operating attention and process control than the activated sludge system, but some problems do exist. The following is a summary of some of the more common problems and cures: (a) excessive organic loading without a corresponding higher recirculation rate, (b) use of media which is too small, (c) clogging of under drain system, (d) non-uniform media size or breaking up of media.

Electrosorption: Electrosorption is generally defined as potential polarization induced adsorption on the surface of electrodes, and is a non-Faraday process. After the polarization of the electrodes, the polar molecules or ions can be removed from the electrolyte solution by the imposed electric field and adsorbed onto the surface of the electrode. Because of its low energy consumption and environmentally friendly advantage, electrosorption has attracted a wide interest in the adsorption processes for treatment of wastewater. Although electrosorption has been shown as a promising treatment process, it has been limited by the performance of electrode material. Activated carbon fibre cloth with high specific surface area and high conductivity is one of the commonly used electrode materials. The surface chemistry of activated carbon fibre has been recognized as a key parameter in the control of the adsorption process. To increase the adsorption capacity, a number of modification methods have been employed [8-10].

The adsorption capacity and adsorption kinetics depend on the surface properties of adsorbent. To increase the potentially low adsorption capacity of any adsorbent, a number of modifications including immobilization of a chelating agent on the adsorbent surface have been employed [11]. The adsorption capacities and the feasible removal rates must be substantially boosted by the modification techniques.

Ethylene diamine tetra acetic acid (EDTA) is the most widely used of the amino poly carboxylic acids. EDTA is a chelating agent, forming coordination compounds with most monovalent, divalent, trivalent and tetravalent metal ions. It combines with metal ions in a 1:1 ratio regardless of the charge on the cation. Activated carbon cloth is known for its effectiveness in removing chemicals from water and wastewater. Loading of C-cloth with EDTA provides a more efficient sorbent for the adsorption of metal cations. Modification of C-cloth with EDTA causes a significant increase in the rate and the extent of the adsorption of metal cations. Procedures based on adsorption of some cations at EDTA loaded high-area C-cloth are shown to be effective for removal of them from aqueous solutions. Langmuir model is more successful than Freundlich model in representing experimental isotherm data for the adsorption of the most of the ions on both C-cloths [8,10].

Graphitizable carbons with a large surface area, a high pore volume and a porosity made up of mesospores can be synthesised by means of the template technique by using mesostructured silica materials as templates. Thus, the silica porosity is filled with a carbon precursor, which is converted into graphitizable carbon after the carbonization step. The pore structure of the graphitizable carbons can be tailored as a function of the silica that is used as template. Thus, a carbon with a well-ordered porosity is prepared from silica, whereas a carbon with a wormhole pore structure is obtained if silica is used as template. Heat treatment of the graphitizable carbon at high temperature (2300°C) gives rise to a porous carbon with a well-developed graphitic order. This treatment leads to a significant reduction in the BET surface area and pore volume with respect to the graphitizable sample.

The anodic oxidation of activated carbon fibres (ACFs) leads to an increase in the surface functional groups without significantly changing the surface area. As a result, the amount of adsorption and the adsorption rate of toxic heavy metal such as Cr(VI) from an aqueous solution increase due to a larger content of the surface functional groups on ACFs.

All those techniques are mainly used by chemical industries that produce wastewater with elevated concentration of heavy metals. One should keep in mind that in these industries precipitation techniques can be used as primary treatment to lower the heavy metals content of their wastewater followed by adsorption techniques to remove the remaining heavy metals.

Membrane Technology: Membrane processes such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) are increasingly being applied for treating oily wastewater. Of the three broad categories of oily wastes – free-floating oil, unstable oil/water emulsions, and highly stable oil/water emulsions – membranes are most useful with stable emulsions, particularly water soluble oily wastes. Free oil, on the other hand, can be readily removed by mechanical separation devices which use gravitational force as the driving force. Unstable oil/water emulsions can be mechanically or chemically broken and then gravity separated. Pre-treatment to remove large particles and free oil is needed, especially if thin-channel membrane equipment is used.

The membrane unit is usually operated in a semi-batch recycle. The wastewater feed is added to the process tank at the same rate as clean permeate is withdrawn, thus keeping a constant level in the tank. The retentive retention containing the oil and grease is recycled to the process tank. When the oils and grease and other suspended matter reach a certain predetermined concentration in the tank, the feed is stopped and the retentive allowed to concentrate. Usually, this result in a final concentrate volume that is only 3-5% of the initial volume of oily wastewater fed to the process tank. The system is then usually cleaned.

Membranes have several advantages, among them: (1) The technology is more widely applicable across a wide range of industries; (2) The membrane is a positive barrier to rejected components. Thus, the quality of the treated water (the permeate) is more uniform regardless of influent variations. These variations may decrease flux, but generally does not affect quality of its output, (3) No extraneous chemicals are needed, making subsequent oil recovery easier, (4) Membranes can be used in-process to allow recycling of selected waste streams within a plant, (5) Energy costs are lower compared to thermal treatments, and (6) The plant can be highly automated and does not require highly skilled operators.

The chemical nature of the membrane can have a major effect on the flux. For example, free oils can coat hydrophobic membranes resulting in poor flux (emulsified oil is usually not as much of a problem, unless it is concentrated to such a high level that the emulsion breaks, releasing free oils). Hydrophilic membranes preferentially attract water rather than the oil, resulting in much higher flux. Hydrophobic membrane can be used, but usually in a tubular configuration that allows a high degree of turbulence (cross – flow velocity) to be maintained to minimize oil wetting of the membrane.

Membrane processes have some limitations: (i) Scale-up is almost linear above a certain size. Thus capital costs for very large effluent volumes can be high, and (ii) Polymeric membranes suffer from fouling and degradation during use. Thus they may have to be replaced frequently, which can increase operating costs significantly.

In spite of the above disadvantages, membrane processing of oily wastewaters, sometimes in conjunction with other methods for treating the residuals, is a commercial success with more than 3000 polymeric UF/MF installations and over 75 inorganic/ceramic units worldwide. Even polymeric membranes are reported to last 3 – 7 years, depending on the severity of the application, due in part to the low frequency of cleaning. Membranes are gaining wider acceptance for two reasons: it consistently produces effluents of acceptable discharge quality and it is perceived to be a simple process from an operational viewpoint.

Membrane technology is widely used for the treatment of wastewater from a broad band of chemical industry that produces inorganic substances.

Biological Treatment Of Chemical Industry Wastewater

Aerobic treatment: In the wastewater treatment sector, biological processes deal primary with organic impurities. Microbial-based technologies have been used over the last century for the treatment of liquid waste domestic stream. The development of these technologies has provided excellent process for the destruction of waste constituents that are readily biodegradable under aerobic conditions. Therefore, processes similar to those used for conventional domestic wastewater treatment have applied successfully to the treatment of many industrial wastewaters.

Aerobic degradation in the presence of oxygen is considered to be a relatively simple, inexpensive and environmentally sound way to degrade wastes. Factors that are critical in the optimal degradation of the selected substrate include the temperature, moisture, pH, nutrients and aeration rate that the bacterial culture is exposed to, with temperature and aeration being two of the most critical parameters that determine the degradation rates by the microorganism.

Soluble organic sources of biochemical oxygen demand (BOD) can be removed by any viable microbial process, aerobic, anaerobic or anoxic. However, aerobic processes are typically used as the principal means of BOD reduction of domestic wastewater because the aerobic microbial reactions are fast, typically 10 times faster than anaerobic microbial reactions. Therefore, aerobic reactors can be built relatively small and open to the atmosphere, yielding the most economical means of BOD reduction.

On the other hand, the major disadvantage of aerobic bioprocesses for waste treatment, relative to anaerobic processes, is the large amount of sludge produce. A relatively high accumulation of biomass occurs in the aerobic bioreactor because the biomass yield (mass of cell produced per unit mass of biodegradable organic matter) for aerobic microorganisms is relatively high, almost 4 times greater than the yield for anaerobic organisms. The sludge present in the reactor effluent can contain residual BOD that may need to be reduced in an additional process, and must ultimately be disposed of as a solid waste.

There are many mechanisms that are utilised by the microorganisms during the aerobic degradation process. Some of these include the attack on the xenobiotics by organic acids produced by the microorganisms, the production of noxious compounds like hydrogen sulphide and the production of chelating agents which are able to increase the solubility of any insoluble xenobiotics, making them more available to the microorganisms and mechanical degradation.

The wastewater from chemical industries may exert a toxic effect on the microorganisms present in conventional activated sludge reactor. Chemical compounds found in these wastewater streams cannot be utilised as a sole carbon source by microorganisms and will vary in toxicity. Inhibition of growth of the microorganisms by these components therefore plays a crucial role in the degradation process, as this can cause the treatment system to fail [12-14].

The key to successful bioremediation technology of some chemical industries wastewater is to modify or optimise the cell/substrate contact time, so that biodegradation can proceed in a reasonable time and potential toxicity of the wastewater of the wastewater to the microflora is reduced.

According to the literature, the best option for bioremediation of this type of wastewater is a membrane bioreactor (MBR) that has been inoculated with activated sludge, which has been shown to effectively treat high-strength organic wastes. On the other hand, the two-phase partitioning reactor has also been effective with toxic substrates [15]. The following section details two activated aerobic sludge systems that have been shown to facilitate degradation of xenobiotics in the presence of toxic compounds.

Membrane Bioreactors: Membrane bioreactors use a combination of the activated sludge process with an additional membrane separation process. A simplified MBR diagram is shown in Figure 2. The two most common configurations are submerged membranes and external membranes.

The advantages offered by MBRs over traditional activated sludge systems include reduced footprints, a decrease in sludge production, improved effluent quality and efficient treatment of wastewaters

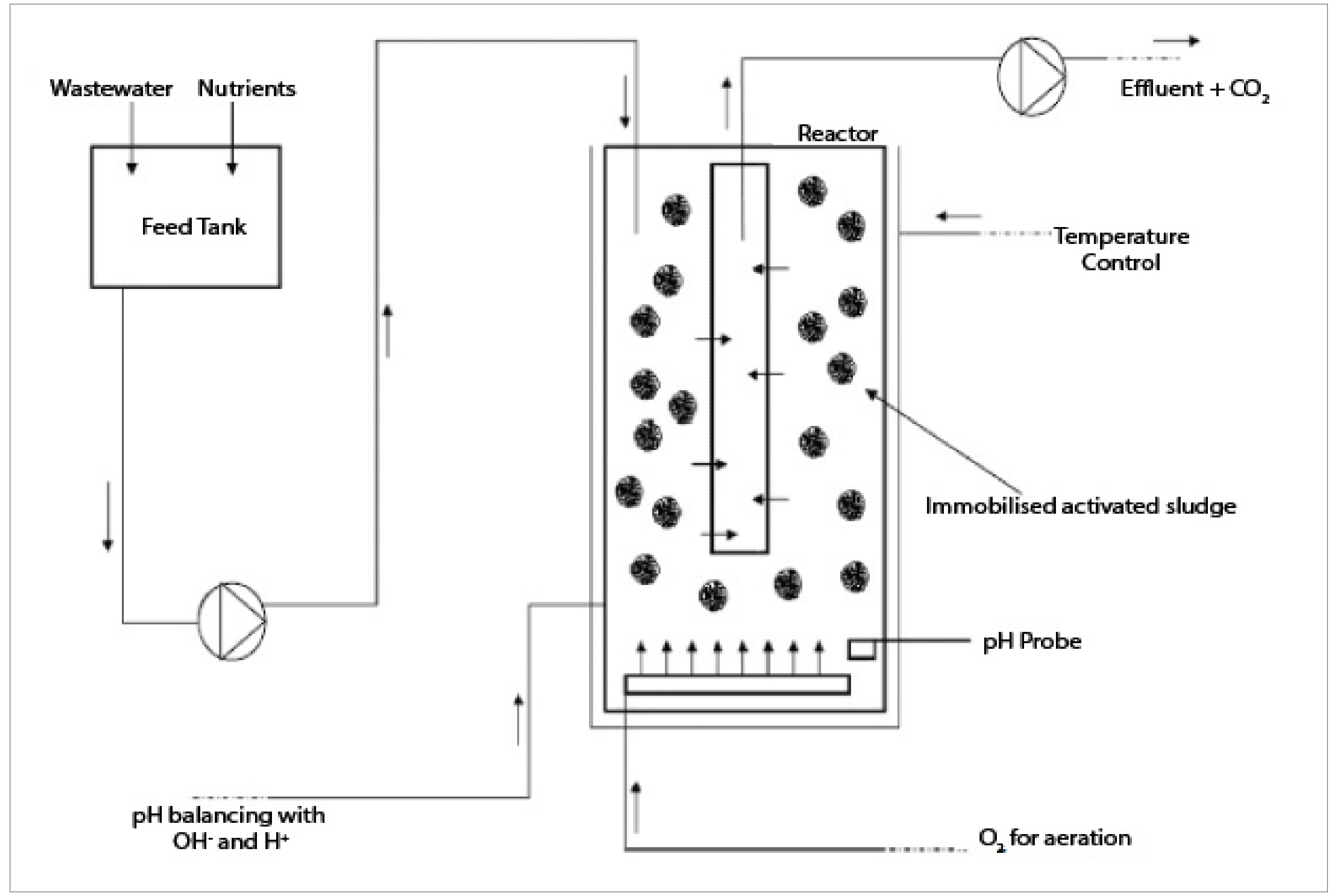


Figure 2: Diagram showing the basic configuration of a membrane bioreactor.

with varying contamination peaks. Some disadvantages of this system include frequent membrane monitoring and maintenance requirements, relatively high running costs and there is a limitation as to the pressures, temperatures and pH to which the system can be exposed.

These reactors have been used in the treatment of a vast range of different wastewaters from municipal or industrial such as pharmaceutical industry [16-18].

Livingston [16] looked at the degradation of 3-chloronitrobenzene from an industrial wastewater stream. It was noted in the study that the degradation of the 3-chloronitrobenzene created chloride ions in stoichiometric quantities, and that transfer tests indicated limited transfer across membranes of the microorganisms and so the levels were not considered to be harmful to the microorganisms. With a flow rate of 64 ml/h, Livingston was able to show > 99% removal of both 3-chloronitrobenzene and nitrobenzene from the wastewater stream with the majority of the carbon entering the system being evolved in the form of CO2. This is an interesting observation and would need to be considered in the design of a reactor with regard to the release of gas.

Details of process design considerations vary greatly depending on the wastewater being treated as well as the type of membrane reactor used. Operational design of the reactor is crucial as the membrane reactors are prone to membrane fouling. This disadvantage has been given as the major reason for MBRs not being as widely utilised in large scale wastewater treatments in comparison to traditional activated sludge plants [19,20].

Numerous papers have been published investigating innovative ways in which membrane fouling can be controlled. The critical flux is a widely accepted parameter used to characterise membrane fouling and can be defined as the flux below which no fouling of the membrane occurs.

Heavy metals found in wastewater streams with low pH values pose significant environmental problems and so many precipitation methods have been introduced but some of these, such as lime precipitation, create carbonates and hydroxides with the latter product being unstable. Membrane Bioreactors containing sulphate-reducing bacteria have been seen as an alternative to the precipitation process with lime.

This technique is used for the treatment of industrial wastewater such those from textile, pharmaceutical and petroleum industry.

Two phase partitioning bioreactor: Two-phase partitioning bioreactors use a nonbiodegradable, biocompatible and non-volatile organic solvent placed on top of an aqueous phase, which is aerated. A simplified diagram of the two-phase bioreactor is shown in Figure 3. These were developed for the high yield production of inhibitory products [21,22]. Potential was later shown for the bioremediation of toxic compounds due to the systems' ability to supply sub-inhibitory amount of the toxic compound to the aqueous phase due to equilibrium considerations [21].

The system is considered to be self-regulatory as the xenobiotic is delivered to the aqueous phase at a rate determined by the consumption rate of the microorganisms. There are distinct advantages to this system compared to traditional activated sludge systems and other aerobic systems, including the limited exposure of the microorganisms to organic components in the wastewater, thus reducing any toxic effects as well as offering distinct and clear increased initial loading rates of xenobiotics. Potential disadvantages include the contact of the biodegrading microflora with the metal ions, resulting in an additional step of biomass removal before effluent discharge.

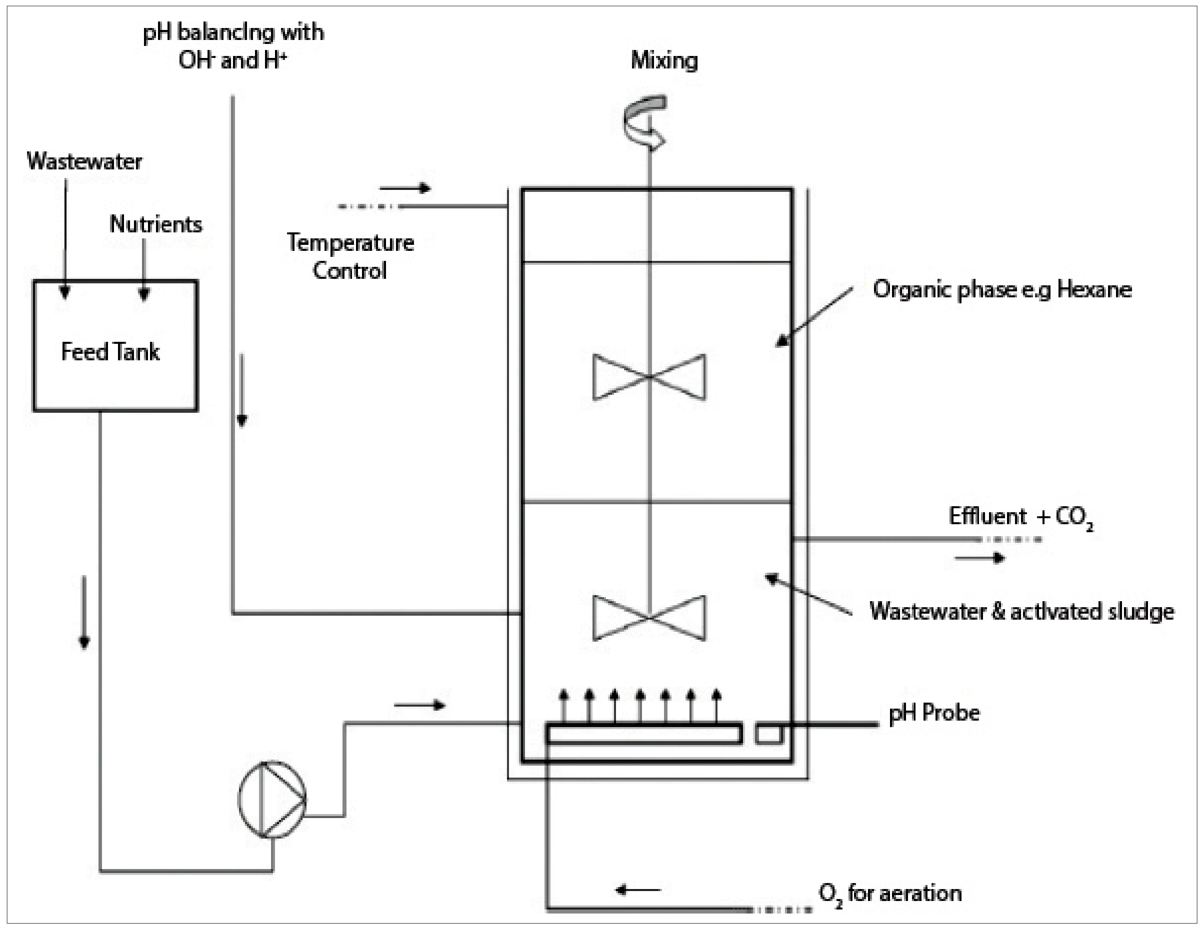


Figure 3: Diagram of simple two – phase reactor configuration.

Several studies have focused on degradation of xenobiotics using this type of aerobic degradation reactor configuration. The scope of research on xenobiotic degradation covers the degradation of single xenobiotics and complex mixtures of xenobiotics in two-phase reactor systems. In one such study looking at the degradation of benzene in a two-phase reactor using Alcaligenes xylosoxidans Y234 it was shown that 63.8% of the benzene added into the system was degraded during a 24 h period while 36.2% was stripped by aeration [21]. Benzene was identified as an important xenobiotic, as it is known to be toxic to numerous microorganisms and is hard to degrade when found at high concentrations. The stripping effect was then adjusted in order to encourage more biological degradation of the benzene and results from the adjusted parameters showed a 99.7% degradation of the initial loaded 7000 mg [21]. These results demonstrate the effectiveness of the two-phase reactor in dealing with potentially toxic xenobiotics. Therefore, all wastewater from chemical industry that may contain toxic xenobiotics compounds can be treated with two-phase partitioning bioreactor.

Sequencing Batch Reactor: A sequencing batch reactor (SBR) is a reactor in which an activated sludge process is carried out in a time oriented, sequential manner using a single vessel for all the phases of the process. The same steps involved in a conventional, continuous activated sludge process (such as aeration, pollutant oxidation, sludge settling, and recycling) are now conducted in batch one after the other.

In an SBR process, each cycle starts with the reactor nearly empty except for a layer of acclimated sludge on the bottom. The reactor is then filled up with the wastewater and the aeration and agitation are started. The biological degradation process begins during the filling step and proceeds, once the reactor has been filled up, until a satisfactory level of degradation of the pollutant is achieved. Then the aeration and agitation are stopped, and the sludge begins to settle. Depending on the time allowed for the sedimentation, anaerobic reaction can occur, which may reduce the organic content of the sludge. Once the sludge has settled, the clear top layer of treated wastewater is discharged and a new cycle can begin. Anaerobic sludge digestion may also be included as one of the steps in the cycle.

The main advantage of SBRs is that they can accommodate large fluctuations in the incoming wastewater flow and composition without failing. The same may not be true in conventional activated-sludge processes, in which an increase in the incoming flow rate results in a lower residence time of the wastewater in the aeration tank and of the sludge in the clarifier, with potential failure of one of them or both.

In addition, toxic shocks or significant changes in organic loading may produce alteration in the makeup of microbial populations of conventional activated-sludge processes, with consequent bulking or process failure. Instead, the wastewater residence time in SBRs can be extended until the microbial population has recovered and completed the degradation process. Similarly, the settling time can be varied to allow complete settling before discharging. In other terms, SBR processes, like all batch processes, are more flexible. On the other hand, the use of SBRs to treat a continuous wastewater flow requires the simultaneous use of multiple reactors and/or the presence of holding facilities to store the wastewater until an SBR becomes available. SBRs have been used also in denitrifying application [23,24].

SBR technology, a periodic discontinuous process can be considered for various types of wastewater treatment (domestic wastewater, medium and low strength landfill leachates, specific organic pollutants, various types of industrial wastewaters and contaminated soils) using diverse types of reactor configurations.

Anaerobic treatment: Anaerobic reactor differs from the aerobic reactors primarily because the former must be closed in order to exclude oxygen from the system, since this could interfere with anaerobic metabolism. An anaerobic reactor must be providing with an appropriate vent or a collection system to remove the gazes (mainly methane and carbon dioxide) produced during anaerobiosis.

Anaerobic microbial processes are known to have several important advantages over aerobic microbial processes: (1) lower production rate of sludge, (2) operable at higher influent BOD and toxics levels, (3) no cost associated with delivering oxygen to the reactor, and (4) production of a useful by-product, methane (biogas). However, anaerobic processes have higher capital and operating expenses than aerobic processes because the anaerobic systems must be closed and heated. Thus, anaerobic bioprocesses for treatment of hazardous wastewater streams are typically limited to treatment of low-flow-rate streams such as industrial effluent.

In the past decade has been an increased research activity in the application of anaerobic reactor technology for treatment of various types of industrial wastewaters, such as those from food processing, textile industry, paper and pulp industry. Anaerobic digestion consists of several interdependent, complex sequential and parallel biological reactions, during which the products from one group of microorganisms serve as the substrates for the next, resulting in transformation of organic matter mainly into a mixture of methane and carbon dioxide. Anaerobic digestion takes place in four phases: hydrolysis/liquefaction, acidogenesis, acetogenesis and methanogenesis. To ensure a balanced digestion process, it is important that the various biological conversion processes remain sufficiently coupled during the process so as to avoid the accumulation of any intermediates in the system. There are different anaerobic reactors such as the Up flow Anaerobic Sludge Blanket (UASB) and the Anaerobic Sequencing Batch Reactor (ASBR), which have been used mainly for industrial wastewater treatment.

USAB Reactor: Anaerobic treatment is now becoming a popular treatment method for industrial wastewater, because of its effectiveness in treating high strength wastewater and because of its economic advantages. Developed in the Netherlands in the late seventies (1976-1980) by Prof. Gatze Lettinga, Wageningen University, UASB reactor was originally used for treating wastewater from sugar refining, breweries and beverage industry, distilleries and fermentation industry, food industry, pulp and paper industry. In recent times the applications for this technology are expanding to include treatment of chemical and petrochemical industry effluents, textile industry wastewater, landfill leachates, as well as applications directed at conversions in the sulfur cycle and removal of metals.

The Essential Components of an UASB reactor is depicted in Figure 4. The UASB reactor has four major components: 1) Sludge bed, 2) Sludge blanket, 3) Gas – sludge – liquid separator (GSL) and 4) Settlement compartment.

The specific of an UASB are existence of granules sludge and internal three-phase GSL device (gas/sludge/liquid separator

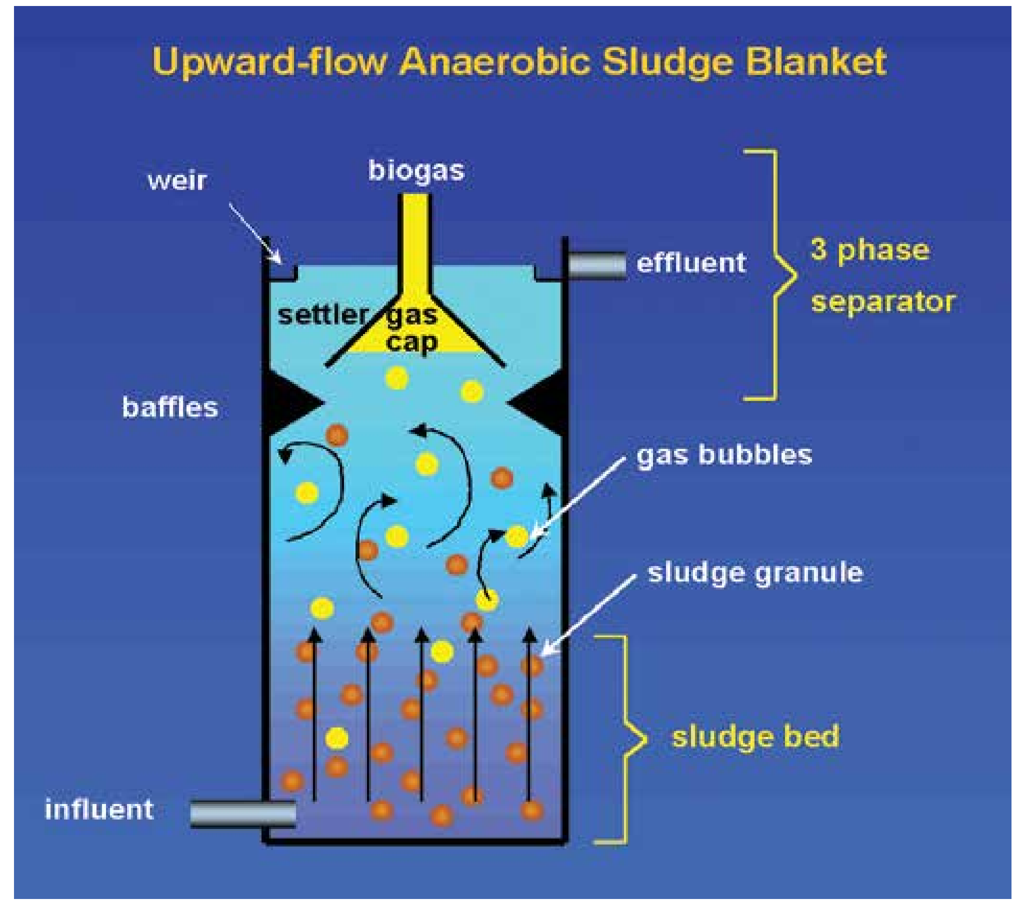


Figure 4: The upward-flow anaerobic sludge bed (UASB) reactor concept.

system). In an UASB reactor, anaerobic sludge has or acquires good sedimentation properties, and is mechanically mixed by the up-flow forces of the incoming wastewater and the gas bubbles being generated in the reactor. For that reason mechanical mixing can be omitted from an UASB reactor thus reducing capital and maintenance costs. This mixing process also encourages the formation of sludge granules.

ASBR Reactor: Anaerobic sequencing batch reactor (ASBR) is a high rate anaerobic process developed by Dague and co-workers at Iowa State University. The promising feature of the ASBR process is that granular biomass can be achieved, and in this way higher biomass can be maintained in the reactor with efficient biomass setting and a long solids retention time (SRT). There are five stages to treatment: (1) Fill, (2) React, (3) Settle, (4) Decant, and (5) Idle.

Anaerobic sequencing batch reactors allow typical biological anaerobic metabolism from substrate consumption to methane and carbon dioxide production and operate according to the following cyclic steps: feed, reaction, settling and discharge [25]. The main advantages of this type of operation are its operational simplicity, efficient quality control of the effluent, possibility of eliminating the settling step for both the affluent and effluent wastewater and flexibility of use in the wide variety of wastewaters to be treated. These characteristics indicate its potential application in situations requiring compliance with strict environmental control standards as well as when sewage is produced intermittently and has variable characteristics as a result of the type of downstream process.

The technological potentials of this reactor have already been assessed for some types of effluents such as food processing wastewater and low-strength synthetic wastewater [25]. However, Zaiat et al. [26] demonstrated that many engineering process features still have to be studied in order to achieve better insight into the operational aspects of this reactor, thereby enabling application in real situations with an optimized procedure.

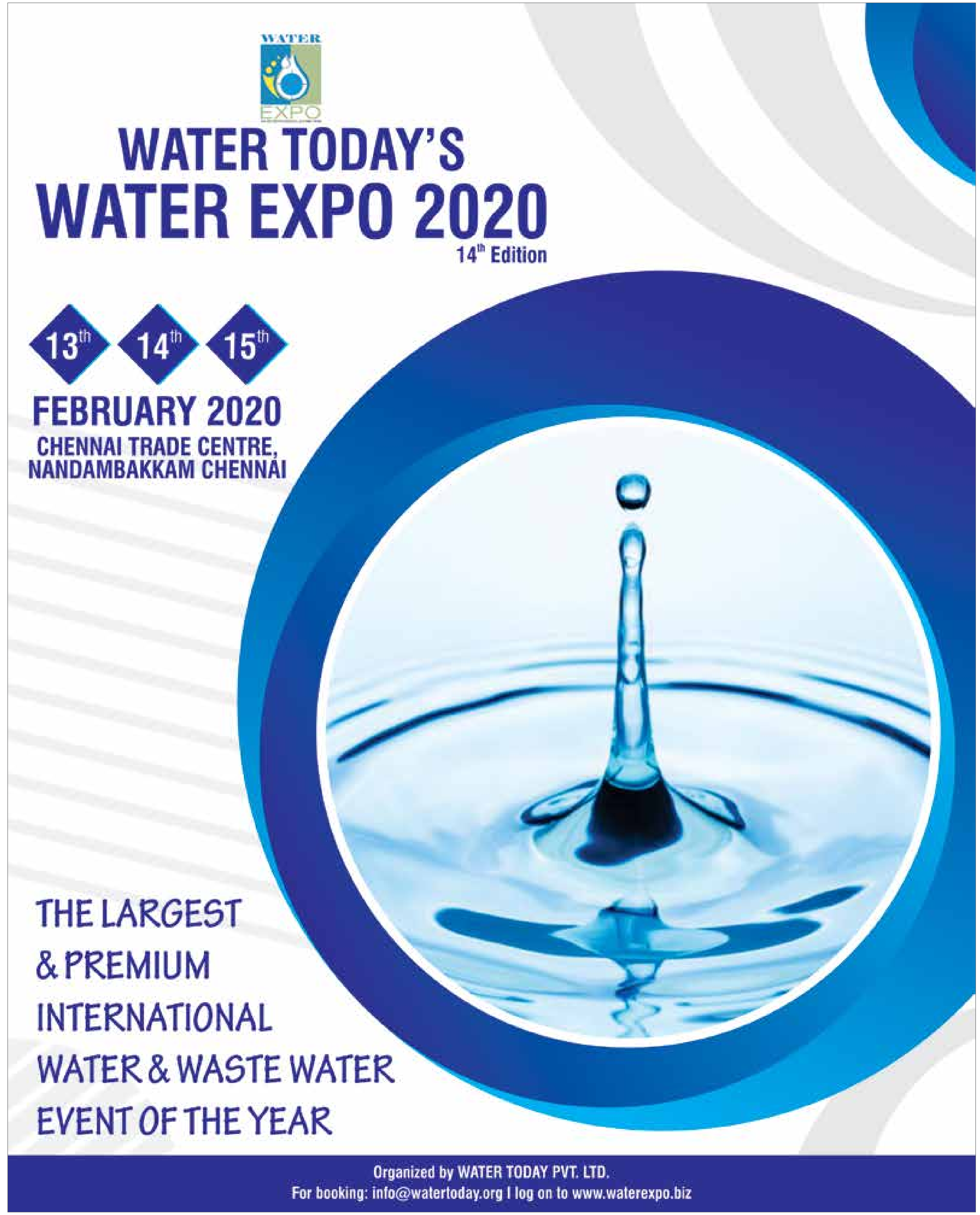
In many municipal and industrial wastewater treatment plants, the sludge effluent from primary and secondary treatment is fed to an anaerobic bioreactor (often termed anaerobic digester or stabilizer) to reduce the residual BOD of the sludge. The anaerobic conditions promote methanogenic microbial degradation of the BOD, thus rendering the sludge fit for landfill disposal. If toxic organic compounds are sorbed to the sludge, the methanogenic conditions of the digester can stimulate degradation of many of these toxic organics. Thus, if the primary fate of toxic organics entering conventional treatment is sorption to sludge, the ultimate fate of the compounds may be biodegradation in the anaerobic digester. Typical operating parameters for the anaerobic digester are 10- to 20- day liquid and solids residence time and a temperature of 35°C. The methane produced from the methanogenic microbial activity is often burned to help heat the bioreactor.

This technique can be used for the treatment of sulphate bearing chemical wastewater, automobile industry wastewater, hypersaline composite chemical wastewater among others.

Integrated Treatment Process: An integrated or hybrid system is designed to take advantage of unique features of two or more processes. In order words, integrated systems are defined here as those waste treatment processes that utilize both aerobic and anaerobic organisms to achieve the desired objective of producing an environmentally accepted and stable final waste product. As more knowledge becomes available on the microbiology of each the two classes of microorganisms, they are likely to be selectively used to solve more difficult wastewater treatment problems by exploiting the specific degradation potentials of each group. In turn, this will require the design of appropriate reactor configuration capable of maintaining the desired conditions for the microbial activity to take place. Some of those systems are now examined.

It is cost effective to treat high-strength wastewater effluents with a combination of anaerobic-aerobic processes. This was recently shown by Eckenfelder et al. [27], whose economic analysis pointed out that if the wastewater has a BOD in excess of 1000 mg/L a combined anaerobic-aerobic process can be advantageous. This approach has been used in different applications, including a recent one involving the combined use of powered activated carbon and both anaerobic (first) and aerobic (second) stages [28,29]. These applications were developed primarily to treat high-strength wastewater. In all these case the reactors used for each stage were of the type described above for each class of organisms.

In addition to the advantages mentioned above, anaerobes can have an additional feature that makes them attractive in



wastewater. Anaerobic organisms have recently been shown to be responsible for a number of reductive reaction processes that could have a significant impact on the treatment of certain classes of hazardous compounds.

In particular, anaerobic organism have been shown to be capable of reductively dehalogenating a number of toxic compounds, such as chlorinated aromatics, that are very recalcitrant to aerobic degradation [30]. Therefore, a possible alternative for the treatment of such compounds is their sequential exposure to specialized anaerobic and aerobic cultures. If the process is operated continuously, it requires the sequential use of two reactors maintained under anaerobic and aerobic conditions, respectively.

Several laboratory-scale investigations have illustrated the potential of sequential anaerobic/aerobic bio treatment steps for textile wastewater [31]. Anaerobic pre-treatment offers several potential advantages such as better removal of colour, absorbable organic halogens (AOX), and Heavy metals. Improved heavy metal removal may follow sulphide production [32], while the improvement of the colour and AOX removal from the rapid reduction and cleavage under anaerobic conditions of the azo groups in arylazo pollutants and of electron-withdrawing chloro or nitro substituent's [33].

The combined activity of anaerobic/aerobic bacteria can also be obtained in a single step if the bacteria are immobilized in bio films since O2 penetration seldom exceeds several hundred micrometers [33]. In addition to providing anaerobic/aerobic zones, fixed film reactors offer the advantages of higher sludge retention time (SRT) necessary to prevent washout of adapted microorganisms, protection against toxicants such as azo dye acid Orange 7, and low sludge production [34].

The combined anaerobic/aerobic process was successfully used to treat saline wastewater for nutrient (COD, N, P) removal. In addition to the removal of these pollutions, the combination of anaerobic/ aerobic processes made it possible to address biological nitrogen and phosphorous removal from saline wastewater.

Chemical Oxidation

Oxidation, by definition, is a process by which electrons are transferred from one substance to another. This leads to a potential expressed in volts referred to a normalized hydrogen electrode. From this, oxidation potentials of the different compounds are obtained.

Chemical oxidation appears to be one of the solutions to be able to comply with the legislation with respect to discharge in a determined receptor medium. It can also be considered as an economically viable previous stage to a secondary treatment of biological oxidation for the destruction of non-biodegradable compounds, which inhibit the process.

A reference parameter in case of using chemical oxidation as treatment process is the chemical oxygen demand (COD). Only waters with relatively small COD contents (≤ 5 g.L-1) can be suitably treated by means of these processes since higher COD contents would require the consumption of too large amounts of expensive reactants. In those cases, it would be more convenient to use wet oxidation or incineration: waste water with COD higher than 20 g.L-1 may undergo auto-thermic wet oxidation [35].

The chemical oxidation processes can be divided in two classes:

- Classical Chemical Treatments

- Advanced Oxidation Processes (AOPs)

Classical Chemical Treatment: Classical chemical treatments consist generally on the addition of an oxidant agent to the water containing the contaminant to oxidize it. Among the most widely used it is possible to emphasize [35] the following classical oxidants.

Chlorine: it is a good chemical oxidizer for water evaporation because it destroys microorganisms. It is a strong and cheap oxidant, very simple to feed into the system and it is well known [35]. Its main disadvantages are its little selectivity that high amounts of chlorine are required and it usually produces carcinogenic organo chloride byproducts.

Potassium Permanganate: It has been an oxidizer extensively used in the treatment of water for decades. It can be introduced into the system as a solid or as a solution prepared on site. It is a strong but expensive oxidant, which works properly in a wide pH range. One of the disadvantages of the use of potassium permanganate as an oxidizer is the formation of magnesium dioxide throughout oxidation, which precipitate and has to be eliminated afterward by clarifying or filtration, both of which mean an extra cost.

Oxygen: The reaction of organic compounds with oxygen does not take place in normal temperature and pressure conditions. Needed values of temperature and pressure are high to increase the oxidizing character of the oxygen in the reaction medium and to assure the liquid state of the effluent. It is a mild oxidant that requires large investments in installations. However, its low operating costs make the process attractive.

Hydrogen Peroxide: It is a multipurpose oxidant for many systems. It can be applied directly or with a catalyst. The catalyst normally used is ferrous sulphate (the so-called Fenton process, which will be presented below). Other iron salts can be used as well. Other metals can also be used as catalyst, for example, Al3+, Cu2+. Its basic advantages are: (i) it is one of the cheapest oxidizers that is normally used in residual, (ii) waters, (iii) it has high oxidizing power, (iv) it is easy to handle, (v) it is water-soluble, (vi) it does not produce toxins or color in by products. It can also been used in presence of ultraviolet radiation and the oxidation is based on the generation of hydroxyl radicals that will be considered an advanced oxidation process.

An option to the ending of hydrogen peroxide to the reaction medium is its production on site. One production possibility is by electro reduction of the oxygen dissolved in the reaction medium [35]. This option is not used very much, because it is expensive and increases the complexity of the system.

Ozonation: It is a strong oxidant that presents the advantage of, as hydrogen peroxide and oxygen, not introducing "strange ions" in the medium. Ozone is effective in many applications, like the elimination of color, disinfection, elimination of smell and taste, elimination of magnesium and organic compounds.

In standard conditions of temperature and pressure it has a low solubility in water and is unstable. It has an average life of a few minutes [35]. Therefore, to have the necessary quantity of ozone in the reaction medium a greater quantity has to be used.

Among the most common oxidizing agents, it is only surpassed in oxidant power by fluorine and hydroxyl radicals. Although included among the classical chemical treatments, the ozonation of dissolved compounds in water can constitute as well an AOP by itself, as hydroxyl radicals are generated from the decomposition of ozone, which is catalyzed by the hydroxyl ion or initiated by the presence of traces of other substances, like transition metal cations [35]. As the pH increases, so does the rate of decomposition of ozone in water.

The major disadvantage of this oxidizer is that it has to be produced on site and needs installation in an ozone production system in the place of use. Therefore, the cost of this oxidizer is extremely high, and it must bear this in mind when deciding the most appropriate oxidizer for a given system. In addition, as it is a gas, a recuperation system has to be foreseen and that will make the obtaining system even more expensive. Ozonation is used in many drinking water plants as a tertiary treatment and also for the oxidation of organic pollutants of industrial (paper mill industry) or agriculture (water polluted by pesticides) effluents.

Advanced Oxidation Processes (AOPs): AOPs were defined by Glaze and Chapin [36] as near ambient temperature and pressure water treatment processes which involve the generation of highly reactive radicals (specially hydroxyl radicals) in sufficient quantity to effect water purification. These treatment processes are considered as very promising methods for the remediation of contaminated ground, surface, and wastewaters containing non-biodegradable organic pollutants. Hydroxyl radicals are extraordinarily reactive species that attack most of the organic molecules.

The advanced oxidation processes (AOPs) are: UV/O3 process, UV/H2O2, O3/H2O2, Fe3+/ UV-vis process, UV/TiO2 (Heterogeneous photocatalysis), H2O2 / Fe2+ (known as Fenton's reagent).

Among various AOPs, the Fenton reagent (H2O22/ Fe2+) is one of the most effective methods of organic pollutant oxidation. The Fenton reagent has been found to be effective in treating various industrial wastewater components including aromatic amines, a wide variety of dyes as well as many other substances, e.g. pesticides and surfactants [35]. Therefore, the Fenton reagent has been applied to treat a variety of wastes such as those associated with the textile and chemical industries.

The advantage of the Fenton reagent is that no energy input is necessary to activate hydrogen peroxide [35,37]. Therefore, this method offers a cost-effective source of hydroxyl radicals, using easy-to-handle reagents. However, disadvantages in using the Fenton reagent include the production of a substantial amount of Fe (OH)3 precipitate And additional water pollution caused

by the homogeneous catalyst that added as an iron salt, cannot be retained in the process [35]. To solve these problems, the application of alternative iron sources as catalysts in oxidizing organic contaminants has been studied extensively. A number of researchers have investigated the application of iron oxides such as hematite, ferrihydrite, semicrystalline iron oxide and crystalline goethite [35]. They generally have observed a greatly accelerated decomposition of hydrogen peroxide but variable amounts of contaminant were lost.

The Fenton reaction was discovered by Fenton in 1894 [38]. Forty years later the Haber-Weiss [39] mechanism was postulated, which revealed that the effective oxidative agent in the Fenton reaction was the hydroxyl radical.

The Fenton reaction can be outlined as follows:

$$M^{n}+ + H2O2 \rightarrow M^{(n+1)}+ + HO - + HO\bullet \quad (1)$$

where M is a transition metal as Fe or Cu

The HO• radical mentioned above, once in solution attacks almost every organic compound. The metal regeneration can follow different paths. For Fe^{2}+, the most accepted scheme is described in the following equations [40].

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{3+} + HO + HO\bullet \quad (2)$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HO_2\bullet + H+ \quad (3)$$

$$Fe^{2+} + HO\bullet \rightarrow Fe^{3+} + HO^{\bullet-} \quad (4)$$

$$HO^{\bullet} + H_2O_2 \rightarrow HO_2\bullet + H2O \quad (5)$$

$$Fe^{3+} + HO\bullet \rightarrow Fe^{2+} + H+ + O_2 \quad (6)$$

$$Fe^{3+} + O_2\bullet- \rightarrow Fe^{2+} + O_2 \quad (7)$$

$$Fe^{2+} + HO_2\bullet \rightarrow Fe^{3+} + HO_2^{\bullet-} \quad (8)$$

Fenton reaction rates are strongly increased by irradiation with UV/visible light [41].

The AOPs techniques are mainly used as a pre-treatment stage for industrial wastewater remediation. These techniques improve the destruction of persistent contaminants.

Wetland To Treat Industrial Wastewater

Constructed wetlands (CWs) are engineered systems that have been designed and constructed to utilize natural processes involving wetland vegetation, soils and the associated microbial assemblages to assist in treating wastewaters. They are designed to take advantage of many of the processes that occur in natural wetlands but do so within a more controlled environment. Constructed wetlands were initially utilized for nutrient removal in residential and municipal sewage, storm water and agricultural runoff displaying a wide range of removal efficiencies. Since 1990s, the constructed wetlands have been used for all kinds of wastewater including landfill leachate, runoff (e.g. urban, highway, airport and agricultural), food processing (e.g. winery, cheese and milk production), industrial (e.g. chemicals, paper mill and oil refineries), agriculture farms, mine drainage or sludge dewatering [42]. The accelerating industrialization in developing countries with an enormous consumption of metals constitutes an environmental contamination hazard. The application of wetlands for industrial wastewater treatment is a promising alternative. In addition, wetlands have significant merits of low capital and operating costs compare with conventional system as activated sludge, aerated lagoon system and so on.

The basic classification is based on the type of macrophytic growth (emergent, submerged, free floating and rooted with floating leaves), further classification is usually based on the water flow regime (surface flow, sub-surface vertical or horizontal flow). Recently, the combinations of various types of CWs (so-called hybrid systems) have been used to enhance the treatment effect, especially for nitrogen. The capability of water hyacinth to purify wastewater is well documented [43,44]. The extensive root system of the weed provides a large surface area for attached microorganisms thus increasing the potential for decomposition of organic matter. Plant uptake is the major process for nutrient removal from wastewater systems containing water hyacinth plants, and it is related to nutrient loading to the system [43,44]. Nitrogen is removed through plant uptake (with harvesting), ammonia is removed through volatilization and nitrification : denitrification, and phosphorus is removed through plant uptake. Treatment systems with water hyacinth are sufficiently developed to be successfully applied in the tropics and sub-tropics where climatic conditions favour luxuriant and continuous growth of the macrophyte for the whole year.

It has been found that the proper vegetation management not only improves treatment effect but also improves substantially wildlife value of the constructed wetland. Davies et al. [45] studied the enzymatic processes responsible for removal and degradation of azo-dyes using constructed wetlands planted with Phragmites sp. It has been found that the proper vegetation management not only improves treatment effect but also improves substantially wildlife value of the constructed wetland. The function of macrophytes within constructed wetlands has been reviewed extensively by researchers including Kouki et al. [46], Türker et al. [47] and Verlicchi and Zambello [48].

Conclusion

The world's chemical industries face formidable environmental regulatory challenges in treating their wastewater effluents. Therefore, this review shouldered the task of passing in revue the different technologies issued to treat industrial wastewaters. Several physicochemical options and biological wastewater treatment processes are widely utilised in the successful treatment of industrial wastewaters. These options are being shown to be technologically and economically feasible. API – oil separator is an excellent technique for oil removal from industrial wastewaters. Both aerobic and anaerobic treatment systems are feasible to treat wastewater from all types of industrial effluents. However, a combination using an anaerobic process followed by an aerobic treatment system is a better option, as it can make use of the advantages of both the treatment processes. Those hybrid systems produce a high removal of toxic pollutants.

Membranes merely serve to separate or fractionate wastewater components, hopefully into more useful and/or less polluting streams, and cannot break down or chemically alter the pollutants. Fouling, not surprisingly, is frequently cited as the most important factor limiting the utilization of membranes in wastewater treatment. Constructed wetlands (CWs) have been implemented as wastewater treatment facilities in many parts of the world, but to date, the technology has been largely ignored in developing countries where effective, low cost wastewater treatment strategies are critically needed. CWs may be an economical option for secondary treatment of stabilization pond effluent, the most common treatment system in use in economically poor countries. Given the tropical location of many developing nations, CWs may be successfully established with plant species acclimated to the tropical environment.

The type of plant and the stage position (first or second unit in the series) seemed to have a major effect on the dynamics of bacterial communities. Advanced oxidation processes face strict limitations, both technical and economical, in their application to the whole site wastewater flow, whereas they are quite effective in converting rather recalcitrant compounds into intermediates amenable to biological oxidation (via recirculation to the inlet of the biological unit) or even better completely mineralizing these compounds when applied in the outlet of a biological treatment facility as a final polishing step. The activated carbons can be used for the removal of metals, chloride, fluoride and COD from industrial effluents. Activated carbon prepared from low cost material, Agricultural by-product materials or modified natural polymers, is considerably efficient for removal of direct dyes from wastewater. Alleviating demand for clean water by replacing it with treated wastewater wherever possible in industry can ameliorate water stress in arid/semi arid mining regions of Africa and Australia.

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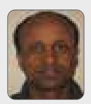

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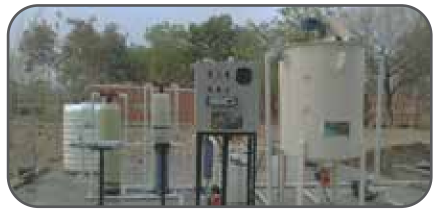
Once Is Not Enough, Recycle



The article discusses the process to treat grey water generated from domestic & industrial sectors, citing two case studies wherein the use of recycled grey water generated from Car wash industry & industrial canteen.

By Dr. Sonali Mokashi

Water is 'life'! Life evolved out of water and exits because of water. It is required everywhere, for all life processes as well manmade industrial activities. In this extensive use of water, it becomes contaminated and 'fresh' water becomes 'wastewater'. Wastewater, depending upon source of origin gets categorized as 'Black' water and 'Grey' water. Black water includes sewage whereas grey water includes water generated from other sources such as kitchen, utensil washing, laundry, wash basins, vehicle washing etc. Other than black and grey water, there is a third category of water which is 'Effluent'. It is generated during industrial processes and may contain toxic chemicals, metals, dyes, diesel, oils etc.

Amongst the three categories of waste water, grey water recycling is effective way of conserving water by using it for non-potable applications. This is because grey water has no sewage, hence compared to black water it has less load of organic waste; similarly, like effluents grey water is devoid of dyes or pigments or toxic metal contaminants. The major contaminants of grey water are from selected known sources and thus can be treated specifically and removed. Mainly it would contain suspended solids, dissolved solids, oils, detergent and bacteria. Such waters can be recycled by treating with relatively simple methods. One can achieve 80-90% recycling efficiency with this. The treated water can be used for several non-potable applications such as vehicle washing, parts

Raw Water Characteristics Of A Car Wash Waste Water

Physical Analysis				
Sr. No.	**Test Parameters**	**Results**	**Units**	**Test Method**
1.	pH	7.2	---	IS 3025 (PII)-1983 CL2 RA.2002
2.	Oil & Grease	40	mg/lit	Is 3025 (P-39)-1991 RA 2003
3.	Colour	2	Unit	IS 3025 (P4)-1983
4.	Odour	Not Agreeable	----	IS 3025 (P5)-1983
Chemical Analysis				
5.	TSS	40	mg/lit	IS 3025 (P15)-1984
6.	COD	315	mg/lit	IS 3025 (P58)-2006
7	BOD	98	mg/lit	IS 3025 (P44)-1993 RA 2003
Microbiological Analysis				
8.	Total Plate Count	2.9 x 10^3	Cfu / ml	IS 1622-1981

Treated water characteristics of car wash waste water

Physical Analysis				
Sr. No.	**Test Parameters**	**Results**	**Units**	**Test Method**
1.	pH	7.1	---	IS 3025 (PII)-1983 CL2 RA.2002
2.	Oil & Grease	0.9	mg/lit	Is 3025 (P-39)-1991 RA 2003
3.	Colour	1	Unit	IS 3025 (P4)-1983
4.	Odour	Agreeable	----	IS 3025 (P5)-1983
Chemical Analysis				
5.	TSS	10	mg/lit	IS 3025 (P15)-1984
6.	COD	91	mg/lit	IS 3025 (P58)-2006
7	BOD	21	mg/lit	IS 3025 (P44)-1993 RA 2003
Microbiological Analysis				
8.	Total Plate Count	1.8 x 10^3	Cfu / ml	IS 1622-1981

The bacterial counts in treated water sample were further reduced by employing UV disinfection.

Summarized comparative results of the above two tables are given below:

Sr. No.	Parameter	Before Treatment	After Treatment	Comment
1.	pH	7.2	7.1	Confirming to ETP norms
2.	Oil and Grease	40 ppm	9 ppm	Confirming to ETP norms
3.	Colour	2 NTU	1 NTU	Confirming to ETP norms
4.	Odour	Not agreeable	agreeable	Confirming to ETP norms
5.	Suspended solids	40	10	Confirming to ETP norms
6.	COD	315	91	Confirming to ETP norms
7.	BOD	98	21	Confirming to ETP norms

washing in industries, crates washing in dairies, floor cleaning, flushing, gardening etc.

Grey water is generated from various domestic and industrial sectors such as housing apartments, industrial canteens, schools, colleges, hospitals, dairies, restaurants etc. All these sectors require huge quantities of water on daily basis for number of washing applications. Cerulean Enviro Tech Pvt. Ltd. owns a patented process for domestic grey water recycling. The process is now being applied to treat grey water generated from above mentioned sectors. Here two case studies of use of recycled grey water generated from Car wash industry and industrial canteen are given.

Use Of Recycled Water By A Car Washing Center - Pune, Maharashtra (A Case Study)

This particular car wash center is a medium sized (100 cars / day) manual car washing center using approx. 250 - 300 L water per car for upper body and under body wash. This generates 25000–30000 L grey water contaminated with oil, diesel, suspended solids, dissolved solids, detergent and bacteria. A

Figure1: The grey water of car wash before and after treatment

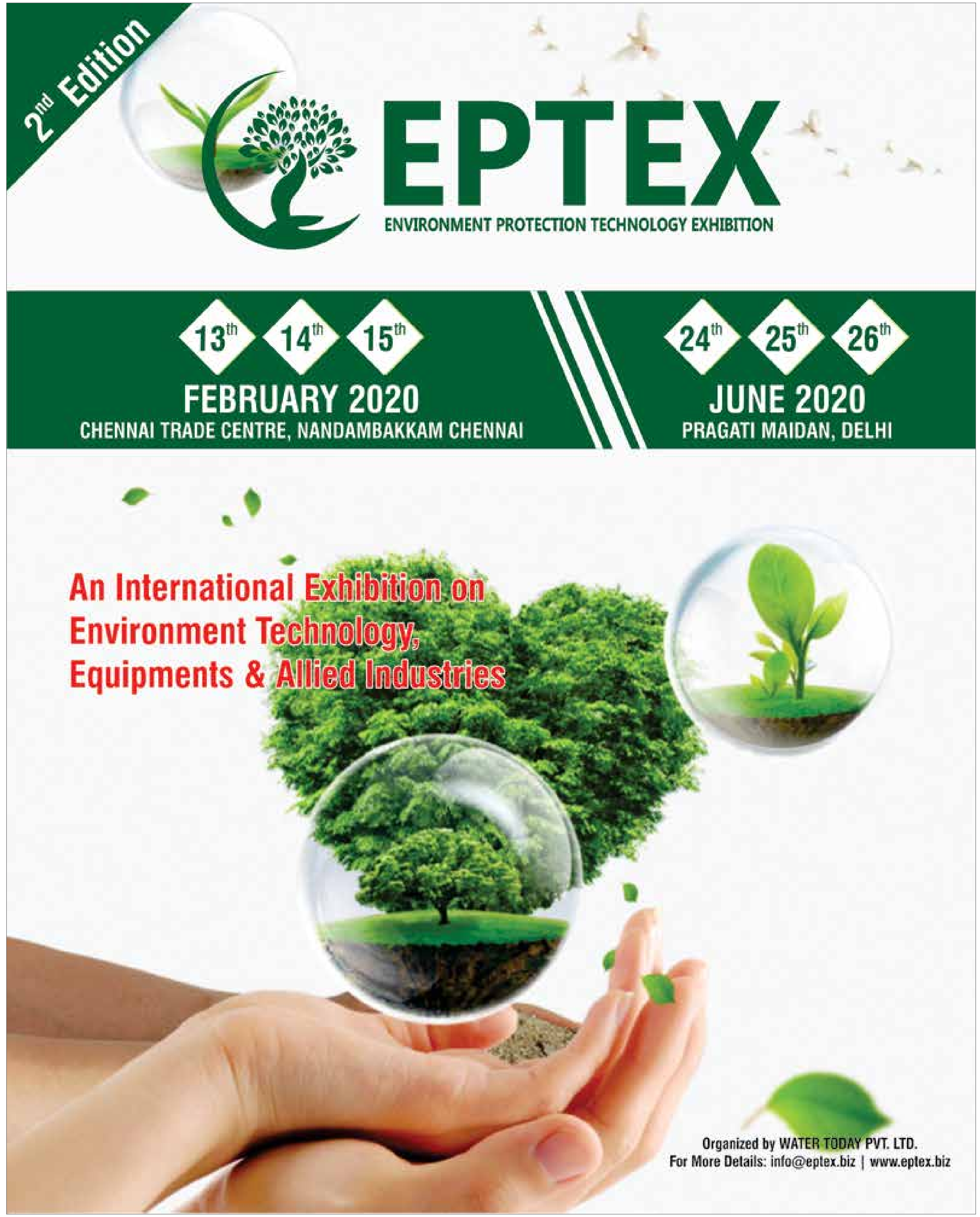
Figure 2: Cerulean automatic car wash grey water recycling plant 25 KLD

grey water recycling plant of 25 KLD capacity with automatic operation was developed by Cerulean which removed oil by using oil skimmer, suspended solids by a patented chemical process followed by filtration through media filters, carbon filters

Figure 3 a: Cerulean automatic canteen waste water recycling plant 10 KLD

Figure 3 b: Canteen grey water before and after treatment

and disinfection. This treatment plant has >90% recycling capacity per cycle. The water generated from this source can be recycled 5-6 times when the plant is properly maintained after which the water is sent to ETP or STP for disposal. Including



the water loses in the sludge removal, backwashing and cleaning, one gets 80% recycling efficiency out of this grey water recycling plant.

The treated water is used for upper as well as under body carwash. There are different capacities plants namely 5 KLD, 10 KLD, 15 KLD, 25 KLD, 50 KLD and 100 KLD. The space requirements and power consumption are very less for these plants e.g., for 10 LKD plant the space required is 8ft x 10ft and electrical units consumed are 5-6 units per day.

At this car wash center because of using recycled water for upper as well as under body car wash approximately 6 lakh liter of water is saved in 4 months of plant operation thereby saving on the purchase of water tanker cost. The company survived in draught situations because of use of recycled water. Figure 2 shows the car wash waste water recycling plant. This emphasizes that for activities such as vehicle washing use of recycled grey water is recommended than using fresh water source.

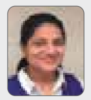
Use Of Recycled Water By An Industrial Canteen - Aurangabad, Maharashtra (A Case Study)

This canteen generates 10 KLD grey water by washing of utensils thus contaminated with oil, suspended solids, detergent, dissolved solids and bacteria. This grey water had high COD and BOD values, acidic pH and turbidity beyond detection limits. It was treated by Cerulean chemical process which comprised of screening, oil water separation, pre filtration, chemical treatment for removing suspended solids, in line chemical disinfection, media and carbon filtration followed by UV disinfection.

The treated water which followed all the parameters within recommended MPCB standards was used for landscaping. Figure 3 shows actual site photograph of the canteen water recycling plant and water quality before and after treatment.

Many water treatment technologies are available and are being used worldwide. It is however necessary to select right kind of technology depending upon the purpose of utilization of treated water. It's time we should think about recycling our own grey water using appropriate technology in order to save water as water is equal to life and conservation is equal to future!

About The Author



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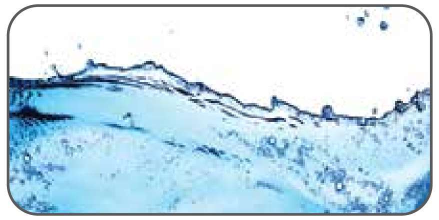
Eco-friendly, Low Cost, Water Treatment Chemicals



This article discusses a new trend of using natural chemicals, instead of synthetic. Read on...

By Uday Bhawalkar

Cleaning drinking water using chemicals, appears a paradox. These chemicals themselves are toxic and utmost care is needed in dosing them. Hence they cannot be used in rural area. Even though they are used in small doses, just enough to kill small creatures, their residual effects need to be studied. Man requires larger dose to get killed but small doses cause cancer! Unfortunately, nobody blames cancer to water quality. Cancer is believed to be caused by fate! And remedy for cancer also involves use of toxic chemicals, to kill more of cancer cells and some of healthy cells.

Actually, chemical water treatment focuses on suppressing the signals of water pollution, instead of tackling actual pollutants. The world is gradually shifting from chemical cleaning to eco-logical cleaning. This article discusses a new trend of using natural chemicals, instead of synthetic.

Yes, Nature also uses chemicals that are more potent, but these cause no hazard because they are not stockpiled. They are produced and used without long storage. They are also produced following laws of Nature. Hence cause no pollution.

Logic oF Water Pollution

Lowest level of water pollution is indicated to eyes. Turbid or colored water, has **first digit** water pollution. Highest level of water pollution has no signals. Instead, the toxic water can look clean, like water in a pond of copper mines or swimming tanks of five star hotels(where aluminum and copper is used to kill algae)! Here there is heavy metal toxicity that causes crime! See http://www.biolab.co.uk/docs/nkpaper.pdf

Second digit of water pollution is indicated to ears, through sound signal. Fish indicates first digit pollution, but frogs indicate second digit pollution.

It is interesting to note that sea water breeds no frogs or mosquitoes, only fish grow. TDS thus misleads us about water quality. In fact, recent research shows that saline water cleans wound better than soap and water! See https://www.mcgill.ca/medicine/channels/news/cleaning-wounds-saline-water-trumps-soap-and-water-257318

Third digit pollution is indicated by skin contact created by biting creatures that cause no illness.

Fourth digit pollution is indicated by short illness and **fifth digit** pollution is indicated by sudden death.

Higher digit pollution has no human life possible, though other creatures that can tolerate higher pollution can survive. Worst pollution has no life possible. Such lakes, however, can look very clean!

Objectives of Water Treatment:

Water treatment strategy should satisfy following objectives:

- No use of toxic chemicals that carry a label: Keep away from children.
- No generation of residue that is toxic and goes to a landfill.
- Should not waste water that is getting scarce.
- Should be easy to use by rural people.
- Should be affordable.
- Cleaning should reduce water pollution digit. Water that has zero pollution, becomes healing or Amrut water. This is the highest quality of water.

BioSanitizer Ecochips Technology:

This innovation is based on 4.6 billion years of evolutionary experience of Nature. It's Nature's Own Technology. BioSanitizer Ecochips are about 1 gram weight and are of about 4 mmX4 mm size. They act as complete water treatment system. They are insoluble in water and hence have long life of several years at steady load of pollution. BioSanitizer Ecochips convert actual water pollutants (which are all inorganic toxins) into active oxygen and natural organics that give sweet Amrut-like taste to water. Active oxygen is produced in a need-based manner and takes care of odor-pathogens-pests and also cracks all toxic organics.

BioSanitizer Ecochips

Grades of Water Quality

We have grade clean water quality into three types. Lowest grade is municipal **tap water.** It is supposed to be suitable for drinking (in spite of heavy metals and chlorine in it). But even the municipal authorities do not drink tap water and use packaged drinking water bottles during their meetings!

Middle grade is produced through use of RO and ozonation and we get ubiquitous Packaged Drinking Water bottles. But RO removes minerals so the craze for low TDS is really a misguided choice. Ion-hungry water can rob body minerals and cause bone problems, for example. RO also removes wonderful natural organic molecules. Nitrates which are worst water pollutants escape %wise more through the RO membranes. No wonder RO water is more acidic, also more corrosive (alkaline water, without added sodium is better for man). To protect human intestines from this corrosive water, slimy nitrate-loving hazardous bacteria form inside lining. We then have to consume higher calories and proteins for these pet bacteria. Their toxic metabolites enter our system. Better water quality is that of Mineral Water that is tapped from Nature far from human interference. Mineral Water, by law, cannot have any man-made water treatment. This shows that we believe more in Nature, than in man-made technologies.

Highest quality is produced by BioSanitizer Ecochips. We get healing water or Amrut Water. This resists recontamination. Even garbage and sewage is produced in healthy conditions (need no treatment), if Amrut Water is used for drinking, cooking and cleaning).

If Packaged Drinking Water is assigned a value of 10 Rs/liter, Mineral Water 50 Rs/liter, then Amrut Water has value of 1,000 Rs/liter. But one can get Amrut Water at cost of 0.1 paise/liter (Rs 1/kL)! Other methods cost about 10 Rs/kL for producing Packaged Drinking Water. By spending Rs 1/kL, one gets total Water & Wastewater Treatment. This is costing for big projects. Small projects cost Rs 10/kL for Water & Wastewater Treatment.

BioSanitizer facilitates Zero Discharge because once BioSanitizer is installed at the source of water circuit, wastewater comes out well treated automatically. It gets utilized for soil. This is the best way to maintain our water bodies clean.

Case Study: Remediation Of An Urban Borewell

A borewell that was producing water problems common with urban borewells, was treated using a single dose of BioSanitizer Ecochips costing Rs 40,000. Tiny compact Ecochips (4 from a pouch) were dropped to settle at the bottom of the borewell. BioSanitizer Ecochips operate best from the bottom of the borewell because the active oxygen generated from the bottom rises through the water column and cleans the water at speed of the pump that may run 24x7.

The results are given below. People have been using a single dose for 10 years at steady pollution loads. The improvement in pH without using any alkaline chemical, is a remarkable act of BioSanitizer Ecochips. Pollution causes acidity and we need ideally water with an alkaline pH of 7.4. Body fluids have 7.4 pH. Cancer cells grow well at acidic pH. But some people produce alkaline water by adding soda bi carb (baking soda). This loads kidneys with extra sodium. Most of health problems start after both kidneys get overloaded. Hence reduction of electrical conductivity (TDS) should be ensured, but without losing useful minerals such as Ca, Mg, K, etc. BioSanitizer Ecochips give us the best mineral balance following time-tested laws of Nature.

			Before BioSanitizer	After BioSanitizer
Parameters	Unit	Desirable Limit	05-Dec-15	16-Dec-15
Colour	Unit	5	1	1
Odour	--	Agreeable	Agreeable	Agreeable
Turbidity	NTU	5	1	1
pH	--	6.5 – 8.5	6.9	7.4
Conductivity	mS/cm	Not given in IS	0.96	0.8
Total Hardness (as CaCO3)	mg/lit	200	431	294
Calcium Hardness (as Ca)	mg/lit	75	116	51
Magnesium Hardness (as Mg)	mg/lit	30	34	40
Total Solids	mg/lit	Not given in IS	520	400
Total Dissolved Solids	500	500	520	400
Total Suspended Solids	mg/lit	Not given in IS	Nil	Nil
Chlorides, as (Cl)-	mg/lit	250	45	33
Sulphate, as (SO_4)--	mg/lit	200	22	16
P-Alkalinity (as $CaCO_3$)	mg/lit	Not given in IS	Nil	Nil
M-Alkalinity (as $CaCO_3$)	mg/lit	200	361	275
Fluorides (as F)	mg/lit	1	<0.2	<0.2
Total Arsenic (as As)	mg/lit	0.01	<0.01	<0.01

conductivity (TDS) should be ensured, but without losing useful minerals such as Ca, Mg, K, etc. BioSanitizer Ecochips give us the best mineral balance following time-tested laws of Nature.

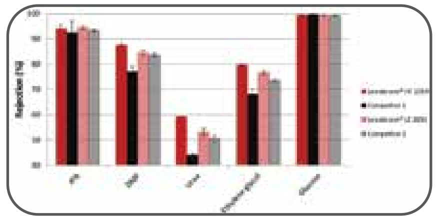
Water Treatment For Flood Prevention & Control

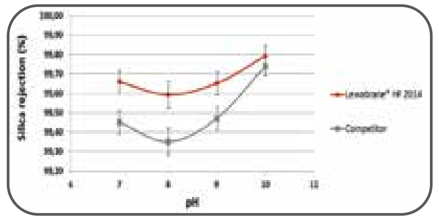
If BioSanitizer is deployed in wells/borewells and ponds/lakes in a city, one gets improved ambiance in addition to improved water quality. Wastewater gets treated automatically and gets soaked easily into the soil. This is natural mechanism to ensure that only clean water gets soaked and polluted water goes into surface water bodies, causing pollution of water and air. Improved ambiance reduces pest problems, reduces crime and facilitates well distributed rain. Excessive rain causing flood is a punishment for spoiling the ambiance. Recent Chennai floods are supposed to be caused by climate change. But one should ask why the excess rain and flood did not take place in Andhra Pradesh. The reply is AP gets BioSanitized water through Krishna and Godavari rivers! Tamil Nadu can take effective steps to prevent future floods. The damage cannot be repaired with money!

About The Author

A B.Tech. and Ph.D. in Chemical Engineering from IIT Bombay, Dr Uday Bhawalkar is the Director, Bhawalkar Ecological Research Institute (BERI) and has 36 years experience in the field of ecosanitation. He has promoted vermiculture ecotechnology through Bhawalkar Earthworm Research Institute (BERI) till 1997 and has received the "Best Technical Paper Award" from IWWA, in 1994. Now, he has actively promoting the use of BIOSANITIZER ecotechnology, through Bhawalkar Ecological Research Institute (BERI), Pune. He has received Dorr-Oliver Best Presentation Award & Bry-Air Best Product Design Award. He can be reached at ecobhawalkar@gmail.com.

Lewabrane® – The Chemistry Makes the Difference





Anyone who has tried out various RO manufacturers knows that, although the membrane chemistry and the design of the elements are similar, there are differences when it comes to permeate performance and rejection. Membrane crosslinking influences rejection and stability, which means it plays a key role.

By Dr. Jens Lipnizki

Since 2012 reverse osmosis (RO) membranes "Made in Germany" are available. The main reason the German company LANXESS entered this market is both the rapid market growth and its existing access to the market through the company's ion exchange resins. It added the RO manufacturing operation to the existing production of monodisperse ion exchange resins in Bitterfeld near Berlin.

LANXESS used tried-and-tested polyamide-based composite membrane technology for this new operation. From the outset, however, the goal was to achieve highly automated production and apply the company's many years of experience in polymerization processes. This led to the concept of highly crosslinked polyamide membranes. With several tens of thousands of membrane elements installed in just under three years on the market, the product launch can be considered a success.

Highly Crosslinked Composite Membranes

A composite membrane comprises three layers – the non-woven fabric (polyester), a polysulfone support structure and the selective polyamide layer. The latter is formed through surface polymerization of trimethylene chloride (TMC) and meta phenyl diamine (m-PDA). Ideally, the network structure should develop fully, but the chlorine-carboxyl group also reacts quickly with water to form a carboxyl group that produces a surface with a negative charge.

This secondary reaction creates a less crosslinked polymer structure and a negatively charged surface. While the lower crosslinked structure reduces a membrane's durability, the negative charged surface leads to interactions with ions that affect membrane rejection. This interaction is depending on the ionic composition of the feed and lead to changing rejection if the feed changes.

The data sheet values for RO membranes are comparable under the specified test conditions, but the differences are apparent in process flows with different cations and anions.

Rejection in the case of inorganic compounds, whose charge can be influenced by the pH, is a particularly good indicator of the electrostatic interactions and thus the membrane's surface charge. The results set out below highlight these effects.

Influence on Rejection

Flat membranes were investigated in test cells and their flux and rejection recorded. The data were normalized to the same flux value to compare the rejection for different fluxes.

The best-known example of rejection changing along with the pH is boric acid. The World Health Organization (WHO) recommends a boron concentration of < 2.4 mg/l in drinking water. This value can be achieved in a single RO filtration process. In some countries that also use drinking water for agricultural

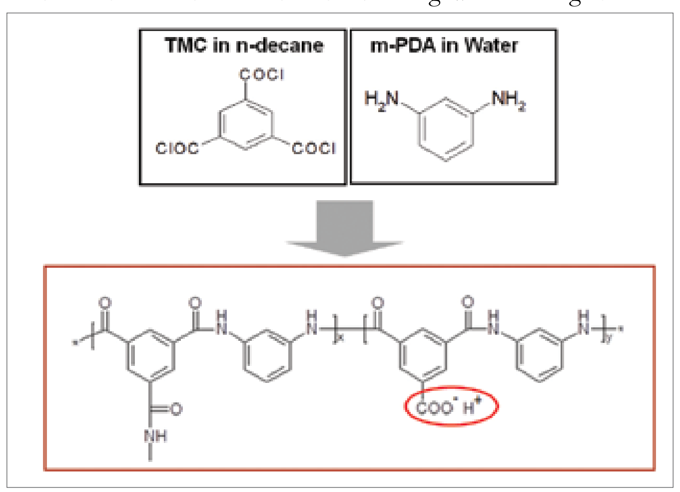


Figure 1: Polymerization to form a polyamide layer

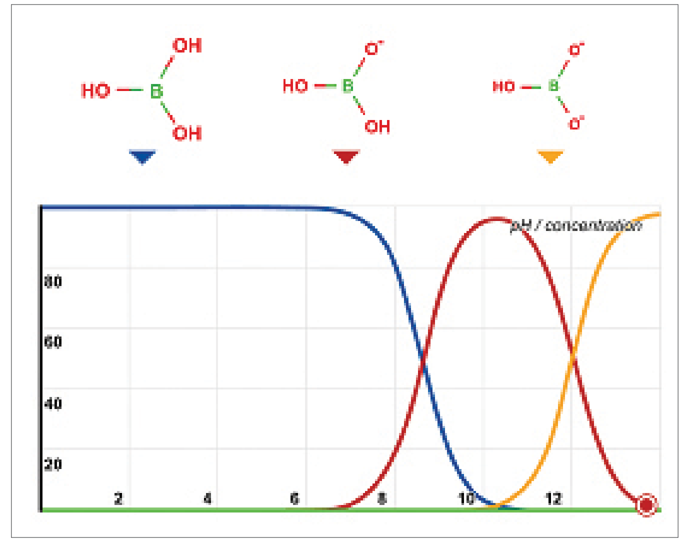


Figure 2: pH dependency of Boric acid

applications, however, the concentration must be < 0.4 mg/l, because crops such as citrus fruits are very sensitive to boron. An RO process with permeate stages is used in this case, with the pH being increased to 10 after the first stage to achieve the required boron rejection. This process makes use of the fact that boric acid has a predominantly negative charge at a pH of 9.5 or higher.

This negative charge and the electrostatic interactions with the negatively charged surface increase the rejection of the boron, which is present in the form of boric acid.

Since the salt concentration is low at the second permeate stage, low-energy (LE) RO methods are often used here. The measurements clearly demonstrate the influence of the surface. While the highly crosslinked LE membrane achieves a rejection of 80 percent at pH values of less than 8, the membrane with less crosslinking only does so at pH values higher than 9. The rejection of the competitor LE membrane depends on the boric acid's charge to a far greater extent than with a highly crosslinked membrane.

A further example that is primarily seen in the treatment of boiler feed water is silica rejection.

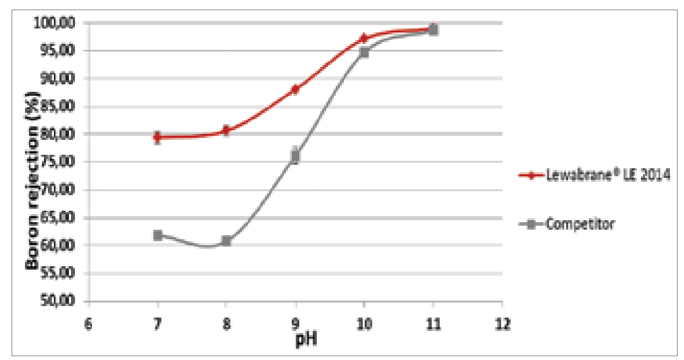
$Si(OH)_4$ + OH- =$HSiO_3$- + $2H_2O$

Silica is soluble in concentrations of less than 75 mg/l. As a weak acid, it is not dissociated in the neutral pH range. As soon as the pH rises, however, the acid dissociates and the rejection increases due to the negative charge. This is clearly noticeable at pH values of 9 or higher. A standard brackish water membrane was used in the test.

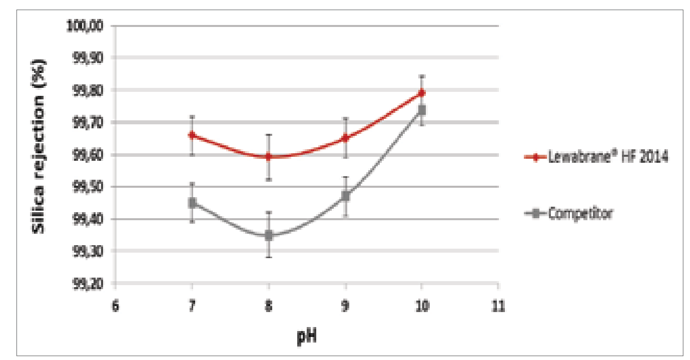
The influence of the temperature was also investigated, which revealed that the higher degree of crosslinking also has a positive impact on rejection at different temperatures.

To explain this phenomenon, it is important to bear in mind that several effects have an impact on the rejection as the temperature increases. Higher temperatures cause the membrane to swell and lead to higher water fluxes due to the decrease in water permeability. This higher flux results in a higher surface concentration of salts, called concentration polarization, which may reduce the rejection.

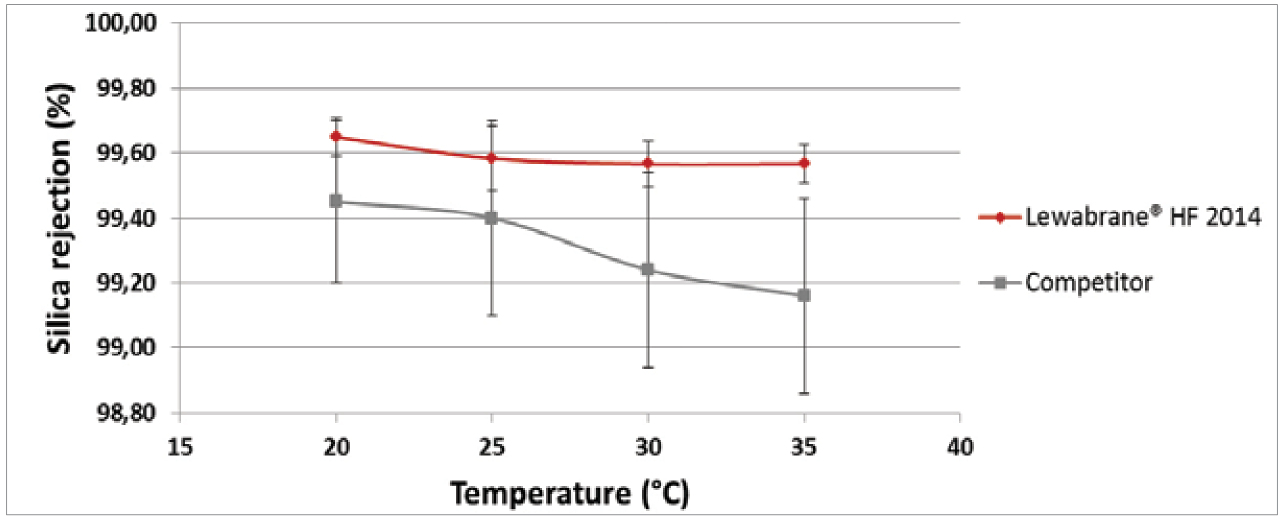
The greater the degree of crosslinking, the less pronounced the swelling as the temperature increases, which means the membrane's rejection remains more constant. In the competitor membrane, the rejection decreases because this cannot be compensated by the increased permeate flux.



Test conditions: boron concentration 200 ppm + 2000 ppm NaCl, pressure 10.3 bar



Test conditions: silica concentration 75 ppm + 2000 ppm NaCl, pressure 15.5 bar



Test conditions: silica concentration 75 ppm + 2000 ppm NaCl, pressure 15.5 bar

Influence on the Process

Especially when treating boiler feed water, consistently high silica rejection is important, as this reduces the capacity of the mixed-bed ion exchange unit. The influence on the mixed bed was calculated using LewaPlus®, LANXESS's design software for reverse osmosis and ion exchange resins, and compared with various silica rejections.

Provided the silica rejection measurements are correct, the following assumptions can be made for the calculation:

Reverse osmosis	Mixed bed unit	Costs
Flux rate: 50 m^3/h	Resin quantity: Strong acidic anion exchange resin: 750l Strong alkaline cation exchange resin: 1500l	Regenerant: HCl €0.35/kg NaOH €0.65/kg
SiO_2 feed concentration 40 ppm	Degree of regeneration 100 g/l of resin	Wastewater disposal €3/m^3
Permeate concentration 0.03 mg/l ions + SiO_2 calculated	The same regeneration conditions apply to all calculations	

Table 1: Costing assumptions

The calculations showed that higher silica rejection resulted in significant savings. While the regeneration costs for the mixed bed are less than €10,000, even at temperatures of 35 °C, they are significantly higher with a lower rejection.

Temperature	20°C	25°C	30°C	35°C
SiO2 rejection – RO [%]	99.65	99.58	99.57	99.57
MB service run [h]	250	226	216	210
MB throughput [m^3]	12,500	11,300	10,800	10,500
Mixed bed regen. costs [€/year]*	7,665	8,479	8,872	9,125

** Including costs for chemicals, water and wastewater disposal*

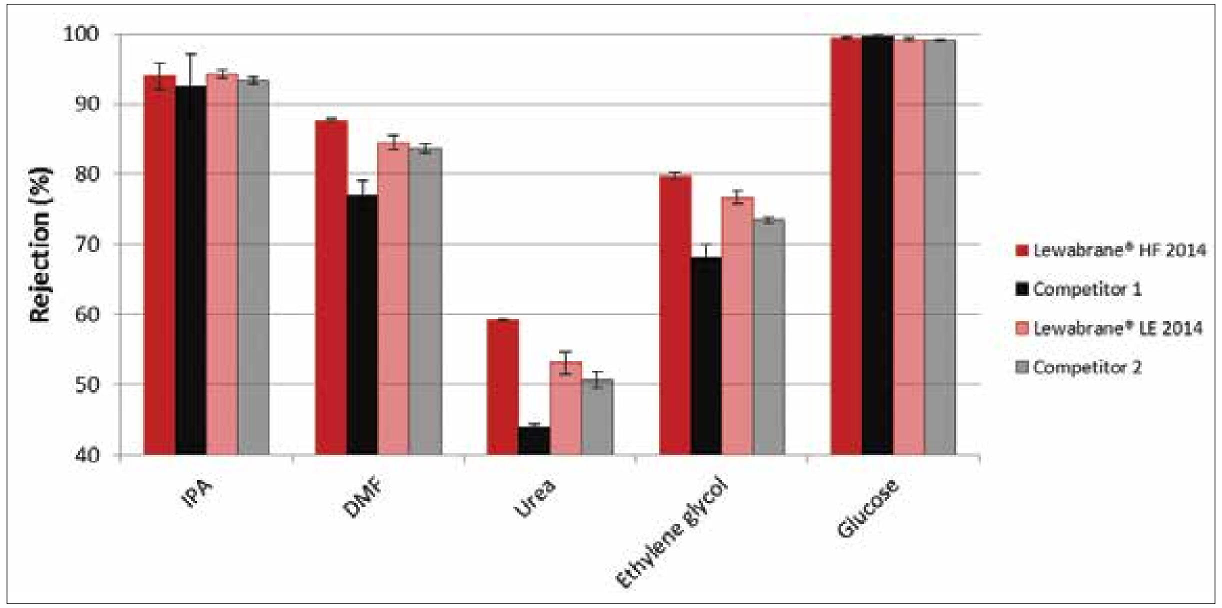
Table 2: Calculations for highly crosslinked RO, HF

Temperature	20°C	25°C	30°C	35°C
SiO2 rejection – RO [%]	99.45	99.40	99.24	99.16
MB service run [h]	192	178	146	130
MB throughput [m^3]	9,600	8,900	7,300	6,500
Mixed bed regen. costs [€/year]*	9,981	10,766	13,126	14,741

Table 3: Calculation for comparable RO process

Rejection of Organic Substances

The rejection of organic substances is much harder to predict, because both the molecule's volume and its polarity affect the diffusion behavior and thus the substance's rejection. Since surface effects are less significant in uncharged substances, however, the higher degree of crosslinking is particularly apparent in substances with a lower molecular volume. In this test, the



Test pressures: HF and competitor1 : 15.5 bar; LE and competitor 2 LE: 10.3 bar

Compound	Molecular weight [mg/mol]	Test concentration [ppm]
Uric acid	60.06	1,000
Ethylene glycol	62.07	680
Dimethlyformamide (DMF)	73.1	750
Isopropyl alcohol (IPA)	60.11	850
Glucose	180.16	700

Table 4: Parameters for testing the rejection of organic substances

rejections of standard brackish water membranes (Lewabrane® HF and competitor) and low-pressure elements (Lewabrane® LE and competitor LE) were investigated. The test parameters used are listed below.

The tendency with organic substances is the same as with inorganic substances. While there are no differences for substances with higher rejections such as isopropyl alcohol (IPA) and glucose, the differences are significant for substances with lower rejections such as dimethylformamide (DMF) and uric acid. The difference is particularly pronounced in the case of standard brackish water membranes (Lewabrane® HF and competitor).

Impact on Flux and Fouling

No long-term effects on the permeate flux have been identified to date due to the higher degree of crosslinking and the resultant denser structure of the polyamide layer. Although fluxes were lower shortly after the startup of a plant fitted with a new membrane, they returned to normal after a brief period.

Similarly, it is not yet clear whether the higher degree of crosslinking or the lower surface charge affects the membrane's fouling behavior, because there are too many different parameters that cause fouling. For example, most organic substances in surface water have a negative charge and are therefore expected to be repelled by a negatively charged surface. In the presence of calcium, however, these substances form a complex with the negatively charged membrane, which increases the adsorption at the surface.

The complex fouling behavior is also one reason why there is still no blanket solution for significantly reducing fouling by modifying surfaces in membrane chemistry.

Future Developments

One possible way of improving fouling behavior is to optimize the flux in the spiral-wound membrane module. Feed spacer developments have already helped reduce low-flux areas. This inhibits biogrowth and the depositing of particles without increasing pressure losses and thus energy consumption. LANXESS will be unveiling an element with a spacer of this kind in the near future.

At present, extrusion technology only makes it possible to produce a structure with a variable length or width during feed

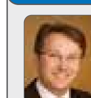
Lewabrane membrane filter elements from LANXESS.

spacer production. However, this would be useful for a spiral-wound membrane module, because the flux in the pressure pipe is not uniform and there is a far greater fouling tendency in the intake area than in the outlet area. In the future, feed spacers could bring about improvements that take into account the different flux conditions in the spiral-wound membrane module in terms of both length and diameter. 3D printing technology opens up new opportunities for adapting the spacer accordingly.

Summary

Anyone who has tried out various RO manufacturers knows that, although the membrane chemistry and the design of the elements are similar, there are differences when it comes to permeate performance and rejection. Membrane crosslinking influences rejection and stability, which means it plays a key role. In addition to being important for industrial applications such as the production of ultrapure water for power plants, high rejection is also becoming ever more significant in drinking water production. Stricter limits and better analysis methods are increasing the pressure to improve water quality, especially in terms of organic compounds. As the example showed, however, higher water quality does not necessarily mean higher operating pressures.

About The Author



Dr. Jens Lipnizki has over 15 years' experinace in the field of membrane filtration. He received a master degree in Chemistry after studying at the TU Dortmund University (Germany) and University of London (Great Britain). In 2003, he obtained his PhD in Chemistry at the Technical University of Denmark (DTU). After completion of studies he worked for more than three years as head of R&D at a membrane producer in Germany before he took care of pharmaceutical and chemical membrane application as sales manager. He can be reached at jens.lipnizki@lanxess.com

Osmotically Assisted Reverse Osmosis Technology for High Recovery Brine Treatment

By Emre Erbil, Basel Abusharkh, Emre Bozkurt & Günseli Mendi

Seawater Reverse Osmosis (RO) desalination plants already operate at the maximum threshold limit of the osmotic pressure, and no further brine minimization is possible with current reverse osmosis membranes. Hyrec's Osmotically Assisted Reverse Osmosis (OARO) system is an upgrade of reverse osmosis technology to overcome the brine chemistry and pressure limitation. OARO process is for dewatering high salinity brines using readily available membranes and equipment. RO technology can be used more effectively with OARO before switching to more expensive thermal technologies. As in Reverse Osmosis, Hyrec's OARO uses pressure to drive desalinated water through the membrane. However, by reducing the osmotic pressure difference between the feed and the permeate sides, and using readily available Reverse Osmosis equipment, ultra-saline feeds can be treated at pressures as low as 70 bars. Arranged in a multi-stage cascade, Hyrec's OARO technology produces desalinated water and a concentrate of up to 260,000 ppm salinity. This process can be used for concentrating any clear or clean brine streams. Most efficient solution to concentrate streams: consuming 1/3rd of the energy and fewer chemicals than thermal methods. Hyrec technology saves up to 40% of the capital cost and 60% of the operational cost compared to thermal and mechanical vapor compression methods. As a brine concentrating technology, OARO can be incorporated into ZLD systems to improve energy and cost efficiencies because of its ability to treat high salinity waters.

1. Introduction

RO, the most efficient desalination method, is the dominant technology ruling desalination market. It has very low energy consumption when compared with thermally-driven technologies. However, conventional RO systems can only desalinate low salinity water sources because of hydraulic pressure limitation. Nevertheless, some improvements allow RO configurations to be used for treatment of higher salinity manucipal and industrial wastewaters [1].Some of these methods, for example, direct pass RO (DPRO), staged RO [2], cascading osmoically mediated RO (COMRO), OARO, cross flow OARO (CF/OARO) [3] and others [4-6]are introduced to increase energy efficiency and brine concentration. COMRO can concentrate from 35,000 ppm to 70,000 ppm TDS at 68.3 bar consuming 3.16 kWh/m3. When it comes to brine concentration, COMRO is far behind Hyrec despite COMRO is 50 % more efficient than conventional RO systems. Wan, C.F. and Chung T.S. proposed a model RO + cPRO and RO + FO [7] to reduce operational and capital expenditure of pressure retarded osmosis (PRO), however this model is designed for energy saving, not extreme brine concentration.Bartholome et. al. [8]introduced an OARO process to increase brine concentration. They simulated energy consumption for 150 g/L TDS feed and achieved 50% recovery consuming 20 kWh/m^3 of recovered water. Even though they don't have a working pilot, their system's energy cunsumption is about twice that of Hyrec system.

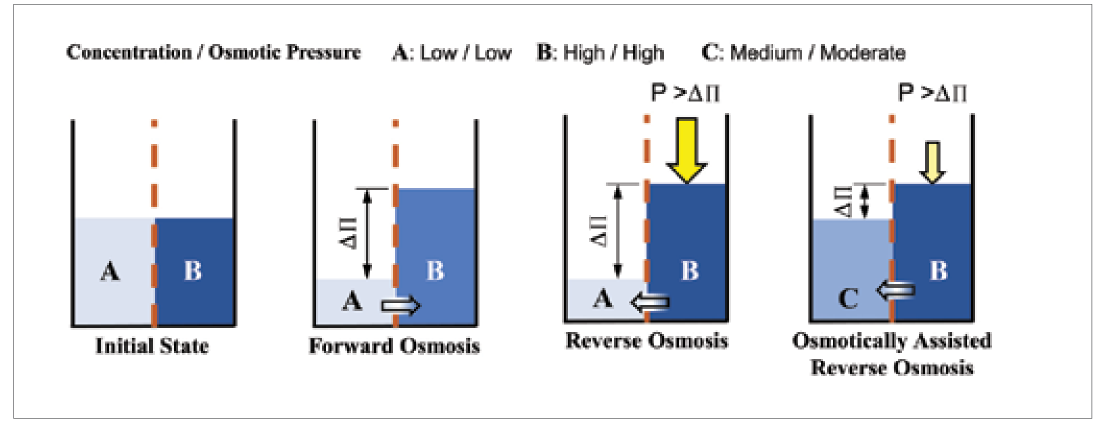


Figure 2.Osmotic flow throught a semi-permeable membrane in FO, RO and OARO

FO occurs naturally when no pressure is applied and RO occurs when applied pressure is higher then osmotic pressuse causing water transport opposite to osmotic pressure difference.

However ultra-high pressure is required for high osmotic pressure solutions such as seawater brine. Osmotic pressure difference is the most cricital barrier in RO technology (Figure 2). Osmotic pressure increases with increased salinity and RO recovery is limited by conventional RO membranes that withstand a maximum pressure of 80 bar.

2. Material & Method

Hyrec introduces a new adaptive technology which provides high-concentration values close to the saturation limit of the source solution by using OARO methodwhich requires significantly lower pressure to drive high concentration solutions.For saline water, Hyrec can concentrate a 3.5% - 4% saline solution to 20%-25% without using any thermal resources or high-pressure systems.

Hyrec technology is unique and patented. It can be placed in any part of a concentration process according to the system design. Acoupled Hybrine® processes is given in Figure 3. Retentate from RO membrane enters into Hybrine® as an input water source at 7% - 8% concentration and exits at 20% as shown in Figure 3. Hyrec operates at fixed and stabilized pressure. It is an adaptive system which manipulates system parameters dynamically to ensure maximum efficiency.

Hyrec is an osmotically assisted concentration system which calculates concentration needs precisely and sets the correct parameters immediately. The driving pressure is always larger

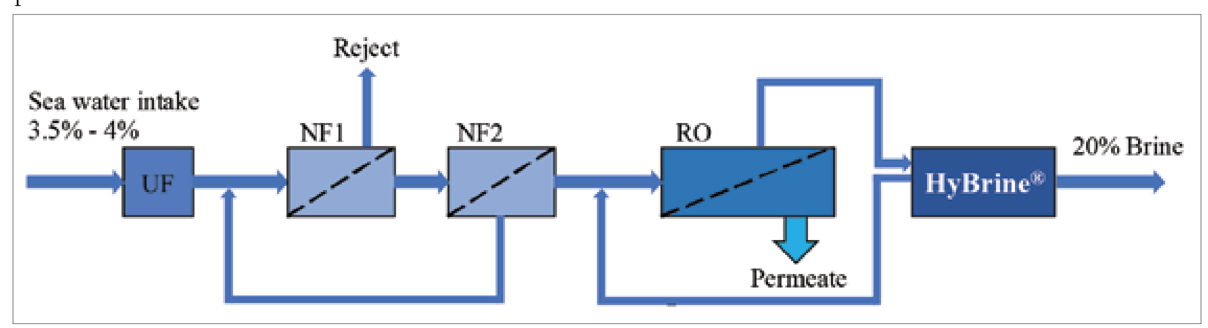


Figure 3.Hybrine® process

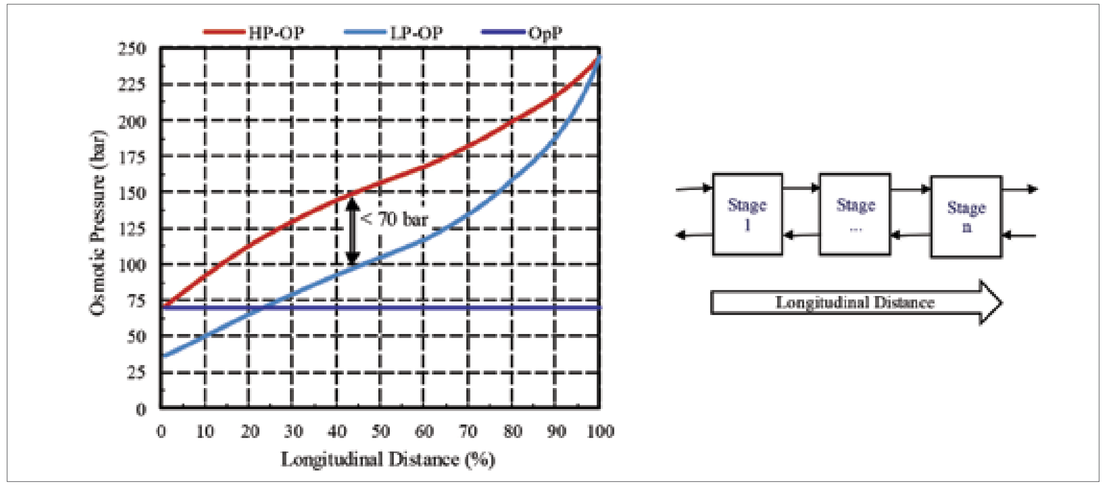


Figure 4.Hyrec system, HP-OP: High pressure osmotic pressure, LP-OP: Low pressure osmotic pressure, OpP: Operating pressure

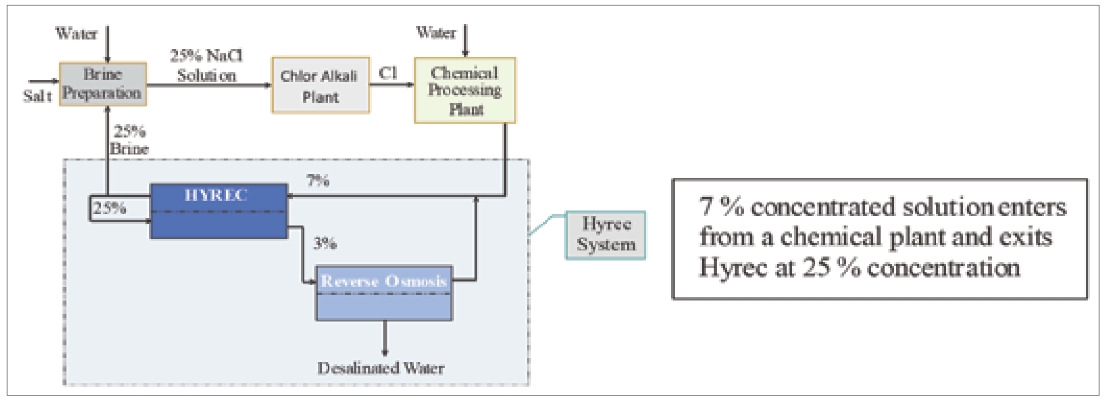


Figure 5.Hyrec-assisted custom configuration

than the osmotic pressure difference between the two sides of the membrane as shown in Figure 4.

This technology depends on the osmotic pressure difference between the high pressure side and the low pressure side of the membrane. Once the retentate exits onestage, it enters a subsequent one.Total number of stages is calculated depending on the application. Hyrec package can be easily adapted to any system where concentration is needed. As an example for FO applications, draw solutions can be recovered by using Hyrec. Hyrec can concentrate 15 % TDS feed up to 25 % or more (close to the saturation limit) efficiently by consuming only 7 kWh/m^3 to 13 kWh/m^3 energy.

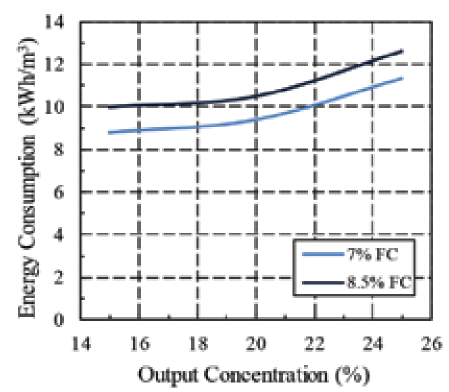


Figure 6.Hyrec energy consumption values per m^3 of recovered water with respect to the Feed Concentration (FC) and output concentration

3. Conclusion

Hyrec is a patented innovative membrane based technology that can increase the recovery of desalination up to 80% and produce nearly saturatedsalt brines of 25% concentration utilizing low operating pressure, less than 70 bar with energy consumption in the range of 5-12 kWh/m3 of recovered water depending on the starting concentration of the feed. Compared to other concentration methods, for example thermal evaporators, MVR and electrodialysis, Hyrec saves more than 40% of capital expenses and 60% of operating expenses.

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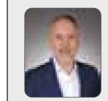


Dr. Basel Abu Sharkh, Ph.D., CEO: Dr. Abu Sharkh is the inventor of Hyrec's technology and he is a founder and partner of Hyrec. Dr. Abu Sharkh received his doctorate in Chemical Engineering from the University of Wisconsin at Madison in 1996. He was a founder of InoChem, a manufacturer of inorganic chemicals, and IDEA Salt and Water Company, a producer of desalinated water and concentrated brine. Dr. Abu Sharkh served as an advisor on water, energy and industrialization to the Saudi Ministry of Economy and Planning and to several international and Saudi organizations, including the Saline Water Conversion Corporation. He has published extensively and owns a number of patents some of which were licensed to the chemical industry. He can be reached at basel.abusharkh@hyrec.co

Sabesp Solves Water Crisis, Avoids Rationing for 9 Million São Paulo Customers

By Perrine Parrod

Solving a Water Crisis

Sabesp supplies water to more than half of the municipalities in the state of São Paulo, Brazil, including the 20 million residents of the metropolitan region of São Paulo. When a 16-month dry spell threatened the water supply from the Cantareira basin, the metro area's main water source, Sabesp acted quickly to avoid water rationing that would be both unpopular and economically devastating. Using WaterGEMS to assemble and calibrate a hydraulic model of the entire water network, Sabesp evaluated 80 what-if scenarios before selecting an alternative that capitalized on the interconnection between producer systems. The solution allowed water to be transferred into the Cantareira system with minimal adjustments to infrastructure. Sabesp estimated that it took 50 percent less time to find a solution by modeling with WaterGEMS, the shortest hydraulic solution time the team of engineers and modeling specialists ever experienced.

Critically Low Flow

Sabesp is one of the world's largest water and sewage services providers, with 24.8 million water supply customers and 21.3 million sewage collection customers in 366 municipalities. The state-owned company serves densely populated urban areas, where the availability of water and sanitation can be uneven.

Over a 16-month period from October 2013 to February 2015, Brazil experienced a prolonged period of extremely low rainfall, along with unusually high temperatures. This produced an alarming water shortage in the city of São Paulo, where water reservoirs dropped to historically low levels and a fraction of their capacity. The inflow rate into the Cantareira reservoir drastically diminished to 15 cubic meters per second (m3/s), an amount half of the previously lowest recorded inflow rate. This extreme drought presented a dire situation for the nearly 9 million residents who relied upon the Cantareira reservoir for daily water use. The drought created the worst water crisis in nearly a century, calling for immediate action to impose unprecedented water restrictions until weather conditions improved and the drought subsided.

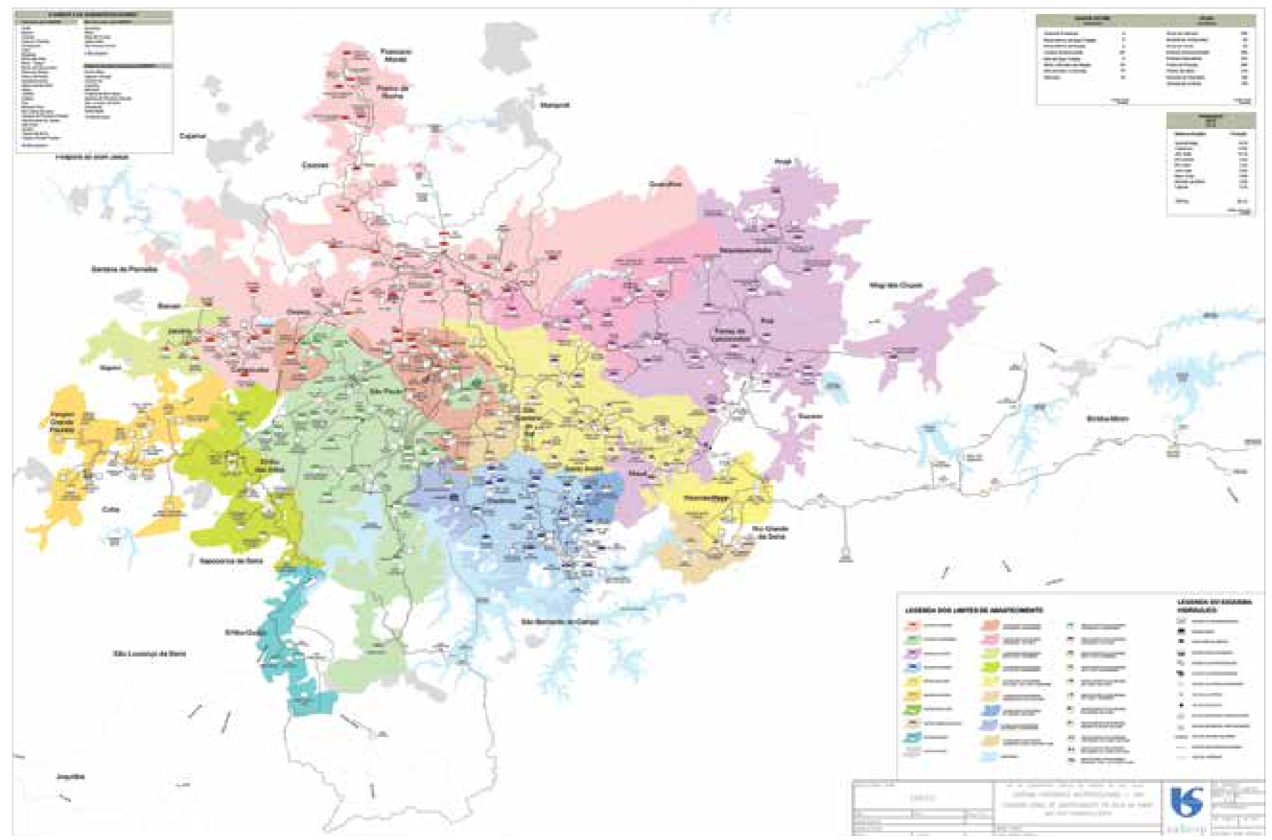
Sabesp considered the drastic measure of limiting customer access to water to only two days per week. Such a rotation would not only be unpopular but also penalize customers at higher elevations, where low pressure would restrict flow. Other issues with rationing included threats to public health, such as poor sanitation and water quality associated with low inflow, and inadequate supplies for hospitals and fire protection. Instead, the company resolved to further integrate and optimize the regional water supply system, known as the Metropolitan Integrated System (SIM), to provide more equal distribution of available water.

Running Supply Scenarios

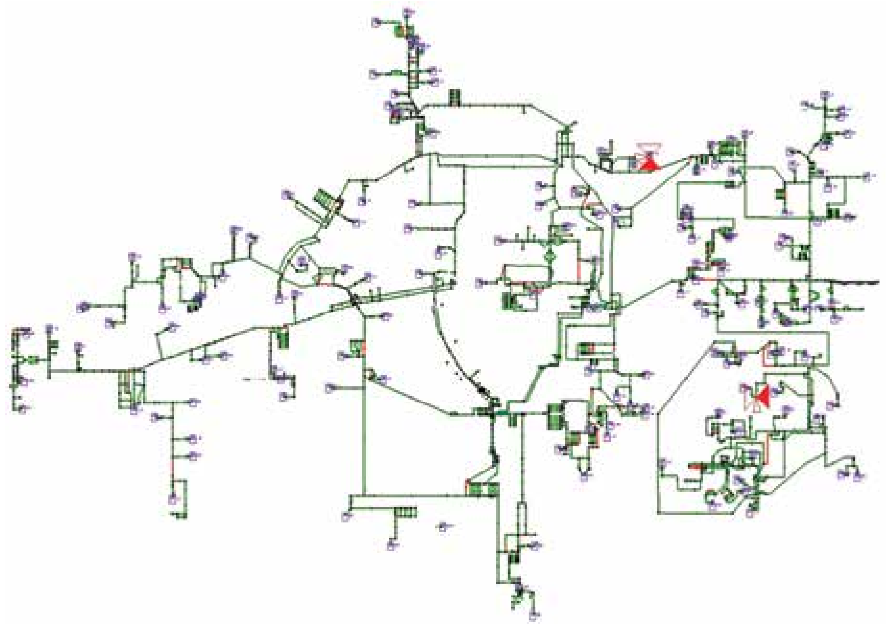
To discover a viable solution for distributing an adequate water supply to its customers, Sabesp undertook a BRL 150 million project utilizing hydraulic modeling with WaterGEMS. The engineering department created 80 scenarios to determine the best possible scheme for transporting drinking water to the affected areas. The hydraulic model also revealed ways to use available water more efficiently, such as reducing consumption, curtailing water loss by identifying and fixing leaks more rapidly by increasing the partitioning of the water network into district metered areas , and by decreasing water pressure.

The project's success relied upon an accurate simulation of the complex water supply system. Comprising 177 reservoirs and 1,300 kilometers of pipeline, the SIM has the capacity to produce water at a rate of 73 m3/s at nine water treatment plants. The distribution network includes 98 pumping stations and 25,000 kilometers of pipeline covering topography with elevations ranging from 740 meters to 1,100 meters. WaterGEMS allowed the engineering department to assemble, calibrate, and validate a hydraulic model of the entire water network with precision and reliability. Interfacing with Sabesp's Geographic Information System (GIS), Supervisory Control and Data Acquisition (SCADA) system, and Process Information Management System (PIMS) accelerated the model assembly process and enabled Sabesp to leverage all of the information and data provided by those systems to make better informed decisions .

The hydraulic modeling revealed a scenario that would have the least impact on the population and pose the lowest operational risk. The reservoirs were emptying quickly under the persistent drought conditions, producing extremely low inflow to the water



Sabesp laid additional pipeline to expand the Metropolitan Integrated System (SIM), the regional water supply system, in order to equally distribute available water to residents of São Paulo, Brazil.



The project connected numerous water producer systems within the metropolitan area to supplement the water supply and limit pulling from the Cantareira system.

supply system. Sabesp offered bonus incentives to customers who reduced their consumption to help to slow the drawdown of the Cantareira reservoir. Meanwhile, the low flows provided an opportunity to modify the infrastructure and enhance the flexibility to transfer drinking water from other water producing systems to the Cantareira service area.

Achieving Quick Results

The hydraulic simulation in WaterGEMS identified the emergency measures that could be implemented in the least amount of time. Sabesp's quick execution of the preferred plan caused minimal disruption to customers. Transferring water from the Guarapiranga dam to the Cantareira system water treatment plants, for example, replenished water where it was most needed, allowed the influx of water from other systems, and reduced withdrawal from reservoirs where water was most scarce.

At the same time, the hydraulic modeling accelerated a metro-area water loss reduction program that identified and fixed leaks, sectorized the network, and introduced more pressure-reducing valves to control pressure that exacerbated leaks. Implementing the necessary water network improvements required construction crews to navigate through intense traffic while meeting traffic restrictions and to limit extensive road closures in the metropolitan region. The engineering department factored these conditions into the WaterGEMS scenario, arriving at solutions that could be accomplished on short deadlines and with minimal disruption to traffic.

Sabesp had to undertake the water loss reduction, pipeline rehabilitation, and other interventions within the legal and budgetary limits imposed upon a government entity. The works had to be executed with available funds and without interfering with operations. The WaterGEMS model calculated where the most water could be transferred with the fewest, least costly interventions in the network. The geo-referenced model also drew upon a decade-long registry of information and images to help the team choose alternatives with the least environmental impact.

Saving Time, Saving Water

Running multiple simulations in the WaterGEMS hydraulic model allowed Sabesp to identify the most viable scenario for supplying more water to its customers amid a severe drought. The whole process took half as long as previous methodologies and delivered effective solutions that could be rolled out quickly, despite daunting constraints. The integration of GIS, SCADA, and PIMS reduced data collection time by 70 percent; model calibration time was reduced by 80 percent. These time savings expedited Sabesp's crisis response time.

Timely and well-executed interventions yielded immediate results. For instance, recovering an abandoned, leaky pipe increased the flow from a pumping station in the Guarapiranga system and diverted that water to São Paulo's financial and medical center. Expanding a booster station in the Guarapiranga system moved more water into the city's western region. With more water flowing from the Guarapiranga dam into the SIM, two treatment plants were expanded to supply more water to the metropolitan area. Altering control structures, reversing boosters, and other measures served to further integrate the provider systems so that the scant water supply could be more effectively distributed.

Sabesp's dramatic initiatives reduced the metropolitan region's reliance on the Cantareira system and slowed the water drawdown from the feeder reservoirs. Modeling revealed ways to introduce more flexibility into the water supply system, so water can continue to be transferred between reservoirs. WaterGEMS enabled the engineering department to test ideas, evaluate outcomes, and make changes where they would be most effective. As a result, water withdrawal from the Cantareira system dropped from 33 m^3/s in 2013 to 13.5 m^3/s in 2015.

Project Summary

Organization

- Sabesp

Solution

- Water Network Analysis

Location

- São Paulo, Brazil

Project Objectives

- Supply water to the metropolitan region of São Paulo, Brazil, during the extreme drought conditions of 2013-2015.
- Model various scenarios to identify a solution that could be implemented quickly and with the least discomfort to the nearly 9 million customers affected.
- Take advantage of the interconnection between water producer systems to prevent the further drawdown of the Cantareira system and supplement the water supply to the metropolitan region.

Products Used

- WaterGEMS

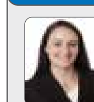
Fast Facts

- Sabesp's solution to transfer water to the Cantareira system prevented millions of São Paulo metropolitan region customers from having their access to water reduced to two days per week.
- Actions to avert the water crisis in the metropolitan region included transferring water across five producer systems, reactivating pipelines, expanding or reversing booster stations, altering control structures, and expanding water treatment plants.
- The availability of water to city residents, commercial establishments, and essential services forestalled the immeasurable impacts of scarce supply, degraded water quality, and massive business closures.

ROI

- The integration between WaterGEMS, GIS, SCADA, and PIMS reduced data collection time by 70 percent and model calibration time by 80 percent, increasing Sabesp's overall crisis response time.
- It took Sabesp 50 percent less time to find a viable solution to the water crisis using the WaterGEMS hydraulic model to run possible scenarios.
- The ability to evaluate 80 scenarios and make informed decisions enabled Sabesp to meet crucial deadlines and reduce implementation costs.

About The Author



Perrine Parrod is a senior product marketing manager for Bentley, for the hydraulics and hydrology product line. Perrine holds a Master of Science in Civil Engineering and a Master of Business Administration. Perrine joined Bentley in 2004 through its acquisition of Haestad Methods, and has ten years of experience marketing Bentley's products and user projects.

Editorial Calendar 2020 - 2021

Issue	Topic
Feb'2020	Chennai Expo Special
Mar'2020	A Review of Aerobic Technologies for the Treatment of Wastewater
Apr 2020	New Techniques & Trends in Filtration Systems and Separation Technologies
May 2020	Water Pages 2020
Jun 2020	ZLD Solutions for Industrial Wastewater Treatment & Delhi Expo Special
Jul 2020	Industry trends in Pumps, Valves & Automation Process Control
Aug 2020	Recent Developments in the Application of MBR, MBBR, SBR, SBBR, Technologies
Sep 2020	IoT & AI: The Future of Water Sector & Bangladesh Expo Special
Oct 2020	Current Scenario in Biological & Chemical Wastewater Treatment
Nov 2020	Sewage Treatment Systems in Smart Cities
Dec 2020	The State of Industrial Wastewater
Jan 2021	Advancements in Membrane Filtration Techniques

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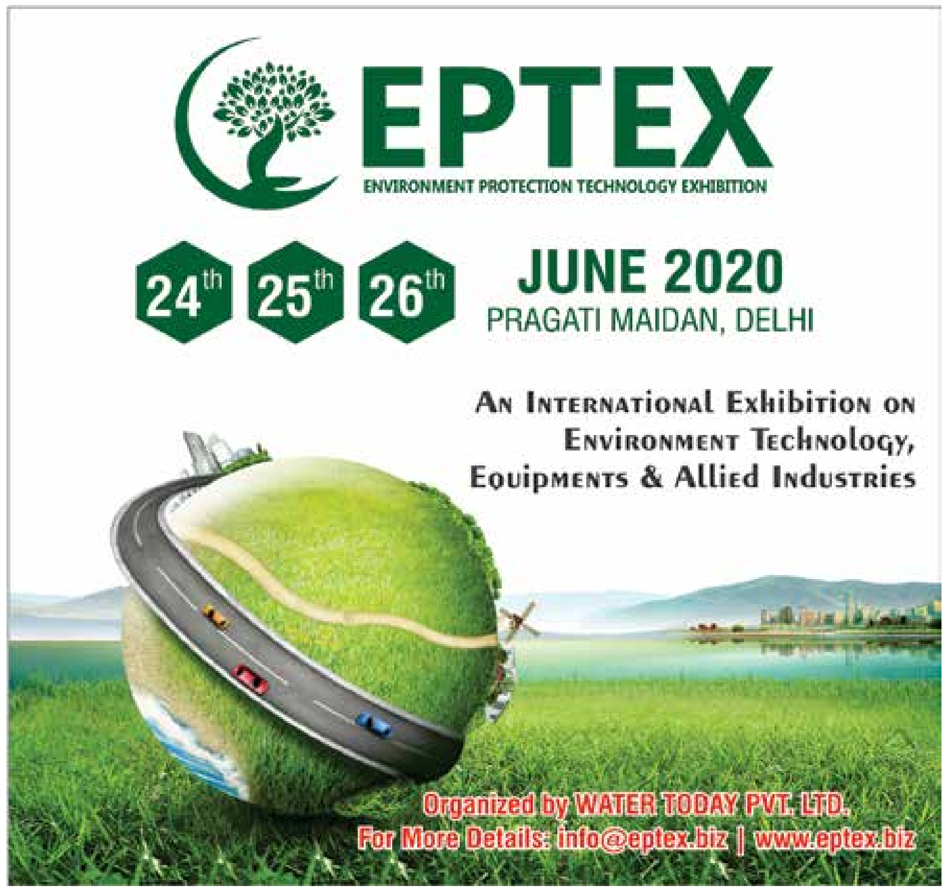
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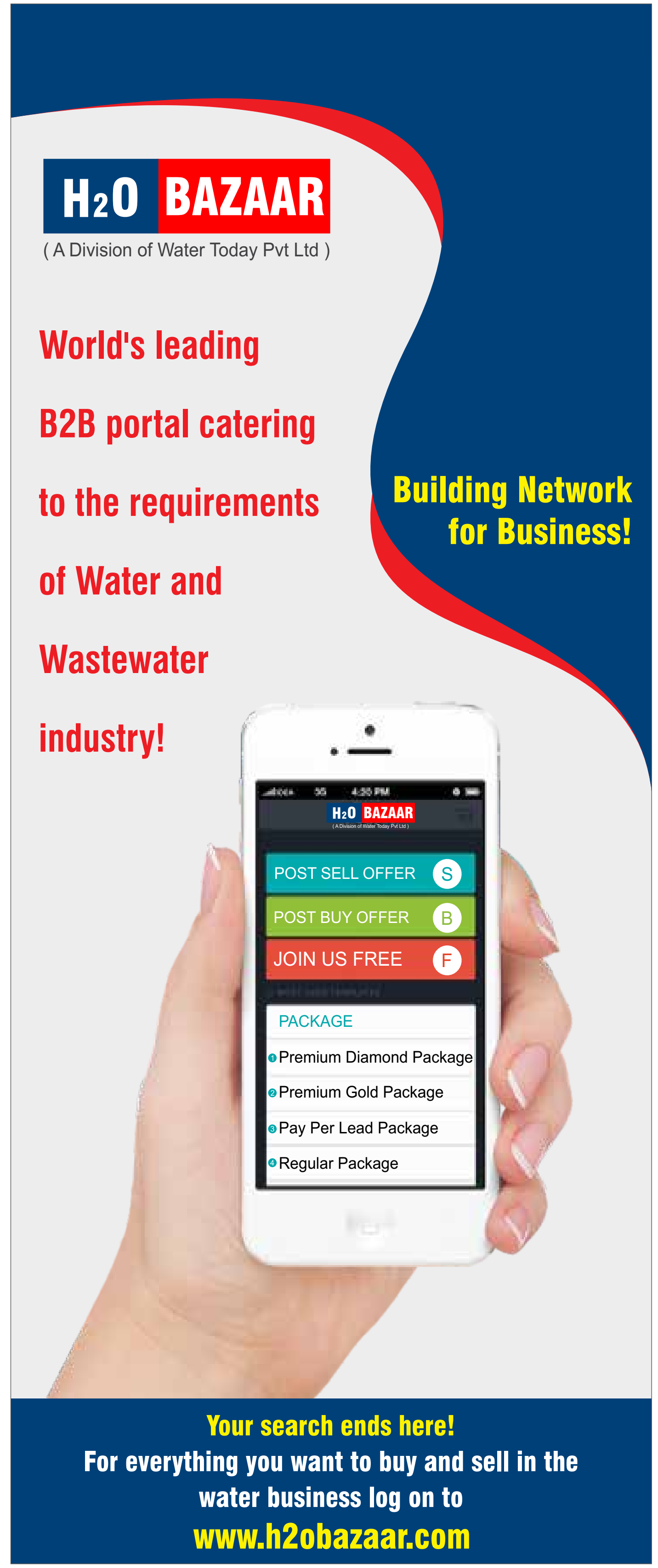
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Editor's Note

The growth of the world's population and industry has given rise to a constantly growing demand for water in proportion to the supply available, which remains constant. Thus, it is necessary to minimize its consumption and it is also necessary to return it to the environment with the minimum contamination load because of the limited capacity of self-purification, hence the importance of wastewater treatment process.

During the last two decades large scale environmental initiatives have taken place in Europe and the United States, these have resulted in strict environmental regulations on the industrial emissions for the chemical industry. It has been necessary to invest in cleaner technologies and in treatments that are more effective. On the other hand, numerous chemical companies have installed effluent treatment systems to meet the recently elaborated regulations of the country in which they are settled or to meet the regulations of the countries with which they trade.

Chemical industrial wastewaters usually contain organic and inorganic matter in varying concentrations. Many materials in the chemical industry are toxic, mutagenic, carcinogenic or simply almost non-biodegradable. This means that the production wastewater also contains a wide range of substances that cannot be easily degraded. The purpose of this issue is to discuss the advantages and limitations of chemical wastewater treatment technologies. Because of the specificity of their wastewaters, the chemical wastewater treatment is required either improving the existing wastewater or developing combinations of various processes. This enables one to emerge with feasible treatment schemes targeting treatment of high strength wastewater. Activated carbon prepared from low cost material, agricultural by-product materials or modified natural polymers, which is considerably efficient for removal of direct dyes from wastewater, is also discussed. The use of membrane in final stage of industrial wastewater treatments is increasing. The chemical oxidation techniques to treat wastewater, classical chemical treatment and advanced oxidation processes, is discussed.

Enjoy Reading.

Naina Shah

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Editor

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