TECH FRONTIERS

# All that crude: Technological intervention in subsurface leftovers

Technology is making it possible to clean up hazardous wastes generated by refining of crude oil, one of the world's most-polluting natural resources

**Technology intervention: The laying of rail lines from the oil fields to shipping ports revolutionised oil transportation**

**SUBHA SEN**

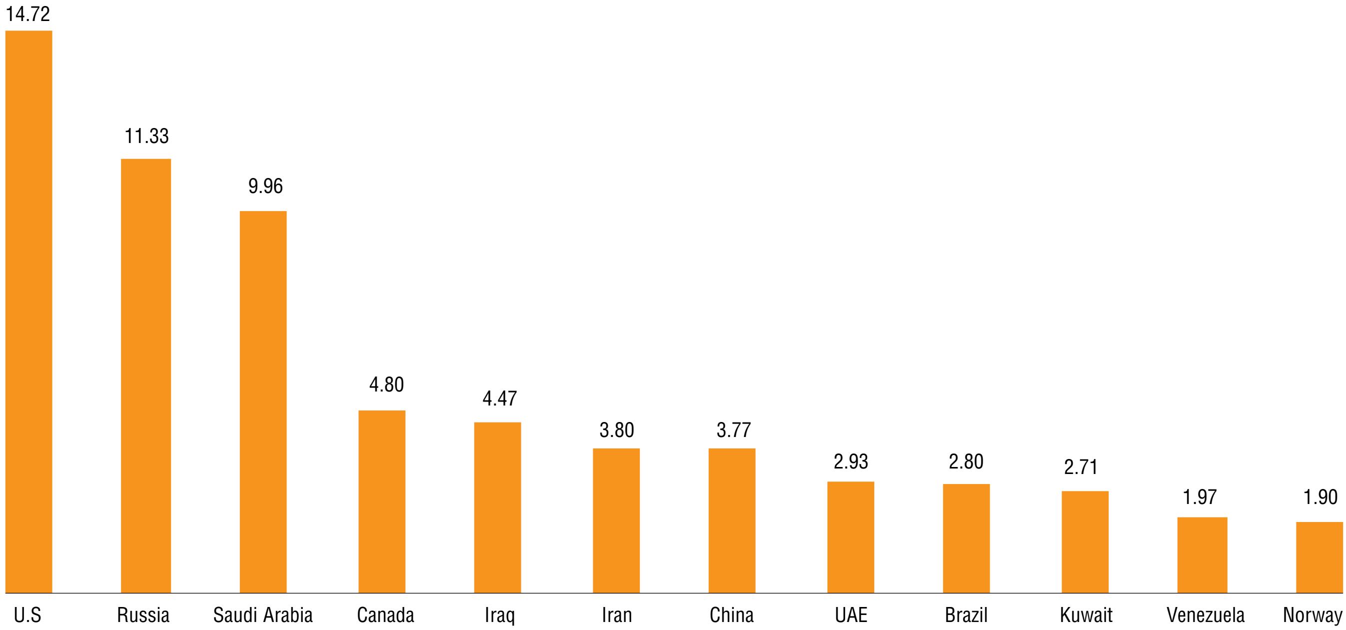
Ms Sen, CEO & MD, Sura-Sol-Inc, Dubai, works on Renewable Energy

THROUGH the past decade, the rising prices of oil barrels have not kept up with the growing rates of inflation. A reason for this discrepancy could be that the term 'crude oil' has been raising many eyebrows. This article explores if crude really does mean bad and what can be done to differentiate between the real values of the product and its generally perceived qualities.

So, the basic questions that comes to one's mind are: What exactly is it about this product that sounds as critical if not as significant as oxygen (O2), the per day use of which is almost like a billion barrels and whose per day production is difficult to meet the demands of its users? What is it that makes it dreaded despite being so useful? Is there any alternative or substitute?

The prudent geological answer is that whether seen with the naked eye or not, it is a natural resource – like water and oxygen – and natural resources have the power to sustain as well as destroy. It is

**Top 12 oil producers, 2017 (million bpd)**



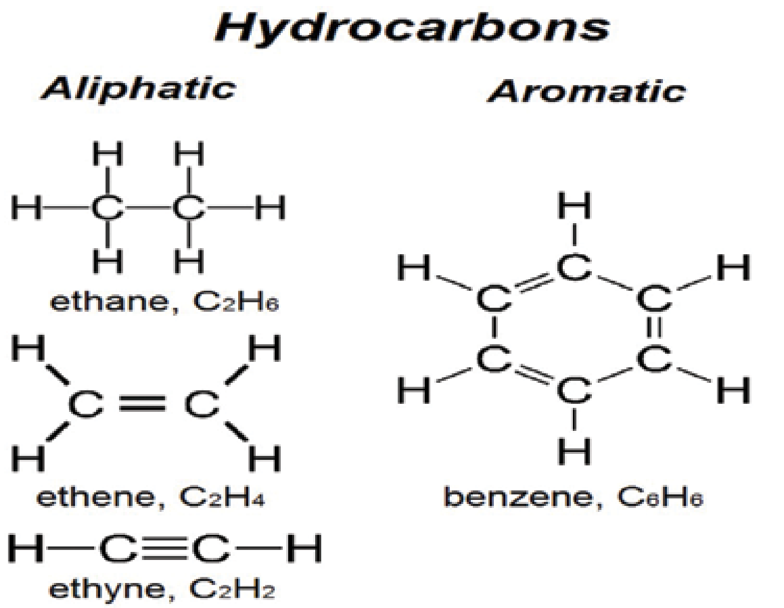

*Source IEA, February 2018*

time people understand and pay due regard to earth's resources by providing as much care to contain the perils of wastes and excess use as they provide to their abundant utilisation.

## The world of hydrocarbons

Robert Zubin, an American scientist, had once said: 'Before agriculture was invented, land was not a resource. Before oil drilling and nuclear fission were invented, petroleum and uranium were not resources.

A land and its soil need a basic technical qualification as well as continuous suitable attention for the effectiveness and sustainability of its produce. Similarly, petroleum and hydrocarbon resources, too, need specific technological interventions in order to ensure sustainable and quality production and essentially their maintenance. Overuse of any resources not only causes depletion, it carries significant detrimental effects for its surrounding environment. Agricultural resources with various overuse cause subsurface water reduction, contamination, and at times excess CO2 emission, causing a disturbance in environmental and ecological balance. In comparison to a thoroughly environment compliant hydrocarbon production or refining centre, the volume of infrastructural activities including business farming that most often ignore biodiversity issues may have greater detrimental impact on the environment than the former.




*Source: Gulf Coast Environmental Systems*

The key concept here is 'environment compliant.' So, before we attempt to address the concept of compliance, allow me to define this chemical compound in its simplest form.

Hydrocarbon, in its simplest organic compound form, contains only hydrogen and carbon. Various forms of hydrocarbon compounds contain various compositions of hydrogen and carbon. For example, chlorofluorocarbons (CFCs) containing only carbon (C), chlorine (Cl), and fluorine (F), mostly used for refrigeration are produced as volatile derivatives of methane, ethane, and propane. However, post Montreal Protocol on climate change, usage of CFC has been banned because its emission contribute to ozone depletion and is replaced with hydroflurocarbons (HFCs), which have potentially lower global warming potential (GWP) despite similar chemical content but, different compounding.

What we refer as hydrocarbon waste, would essentially be any waste matter that has waste component of hydrocarbon – which could come from any industry or rather most industries that use any hydrocarbon by-products for processing or as ingredient in the bill of material (BOM) of that component or as agents to augment such processing. For instance, petroleum jelly, a major component of beauty products, is a hydrocarbon by-product. This obviously states that it is not all crude around the infamous crude!

The fact is that crude or essentially subsurface hydrocarbon, like most other natural phenomena, has some inherent nature of its own and its basic forms, various as they are, are potential sources of power. Exactly like the Sun above in the sky, hydrocarbons have their domain beneath the earth – and that is necessarily not hell and neither does crude or fossil-fuel necessarily rule the hell. That is where this enormous source of energy lies in virtually all possible forms – gas, coal, shells, corals, even petroleum, and what is more, even as water – some of which are yet to be discovered.

Drilling through the earth means reaching those natural resources, not usually noticed by the naked eye. Millions of cubic metres of hydrocarbon fluids and water are used in oil and natural gas. Given its inherent cleansing properties, water is the medium that gets polluted trying to mitigate the harming, polluting, stubborn, hardened factors across most of all fossil-fuels in their various states or forms on a daily basis.

Oil and gas field fluids usually are a mixture of produced water (PW), liquid or gaseous hydrocarbons, dissolved or suspended solids of TDS (total dissolved solids), TSS (total suspended solids) and injected fluids for production, lifting, and additives. Dissolved solids are a measure of the percent content of all inorganic and organic substances dissolved in any liquid, whether in molecular, granular, micro-granular, or ionised form whereas suspended solids are solids/micro-granular suspended solids in water that can be trapped by a filter.

What was critically important had been to assign a dollar value to not only what was being fetched but also to what was not getting fetched, what was falling through from the lifting, what was happening after the petrochemical was getting processed inside a factory, what was getting left over or reducing the production capacity and affecting the quality of the produce. The cynical yet factual reason most often is that the aquifer fetches sludgy, contaminated, inconsumable water due to internal contamination with various physical, chemical, and biological seepage into the source of water. For consumption whether for agriculture, bathing or for drinking, given the extent the earth has been dug up, it is probably the most critical task to run a test on all water across the board – without discrimination given the possibility of dissolved pollutants and other contaminants across sources of water –especially that's fetched from under the ground.

## Centrifugation

Centrifugation is a widely used easily implementable physical process to carry out water treatment where at high rotational speed centrifugal force is applied to separate the solids from the liquid.

The volume of produced water (PW) is much larger in oil production than in gas production. Water or oil, both remain unpolished, unless treated adequately for their specific usage. Those emerging from the subsurface deep down the earth along with hydrocarbon produce, post production, are disposed via uncared cracking, disposal of waste via reverse boring, releasing unused, untreated water from upstream well drilling and downstream refineries, containing dissolved harmful factors that such rampant deep boring expose the potable water to. Unfortunately, while such drilling happens, the entire content of crude does not necessarily get lifted with the watery oil or the oily water. The cracks from fracturing, the boring and the reverberations from the sound and fire, the leaks and spills, trapped and pressed in the subsurface, tend to create severe contaminations in the subsurface fluids.

Both for subsurface water and fossil-fuels, over the last decade, there has been in-depth technological development for treatment of the extract or the 'produce' and since 80-90 percent of the treated water is re-injected back for further extraction with maximum performance, well fluid purity is critical to protect the reservoir from damage as well as clogging porosity of the wall. Hence well fluid and pipeline fluid purity is extremely critical to not only ensure proper protection of the reservoir; it is very important for the produce fluid storage tanks and distribution pipeline walls and bottoms in order to: maximise well performance in re-production; maintain water-oil ratio (WOR); and monitor quality of PW at the time of production during distribu-

## Examples of Centrifugation

tion and at delivery at the refinery.

Apart from typical oilfield production upstream, mid-stream or downstream, and the activities of the distribution pipeline and refinery, various other industrial hydrocarbon waste management has remained a serious gap between the continuous technological advancement in petroleum by products usage in such operations and, most importantly, identifying responsibility of the waste disposal and extent of the harm from such industries as well as the onus for correction. Few defined technologies have become critical in regard to waste treatment for social and environmental health. In terms of industrial waste, defined specific processes are available in treatment and management of all-round waste and water treatment. Similarly, brine completion fluids filtration and polishing filters for reinjection of water are two important critical filtration methods in hydrocarbon treatment. Another challenging filtration application is oily water treatment or produced water filtration.

Treatment and filtration of these fluids or PW are required to go through the following critical steps of sophisticated technological methods:

## PRE-TREATMENT

Usually 80-90 percent of the produced water is re-injected back for re-production and in salt-water disposal well (RO). Various problems are noted during such re-injection without treatment of the water that affected production rates as well as the WOR. The other issues noted are:

1. The PW is extremely sludgy, causing porosity of the reservoir walls to clog.
2. The water is not recycled or treated for reusability despite water being such a critically costly commodity.
3. The third and somewhat more serious concern would be that the PW is carrying such sludgy fluids through the pipeline to the refinery is discharged into the surrounding agricultural fields after the processing, which is essentially harming every component in the distribution cycle – the soil and salt-water RO wells and permeating to the agricultural fields.

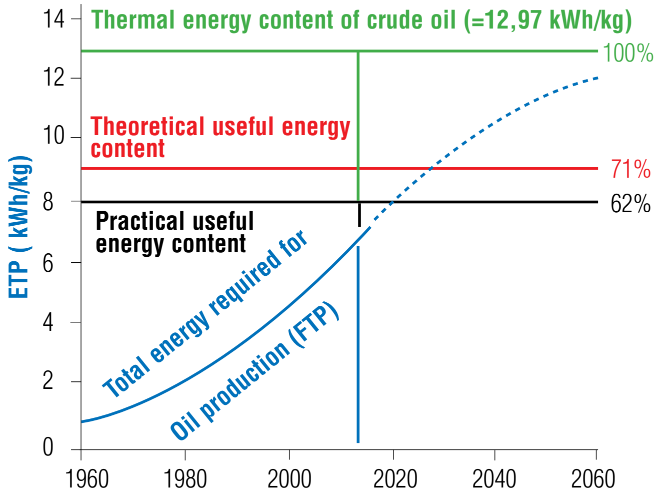
The severe revenue loss including loss due to violation penalty and so on led to serious technological R&D being taken up which came up with essential pre-treatment of the well fluids and PW before reusing and disposal.

Pre-treatment before re-injection processes commercially used were focused mainly on removing oily grease, TSS, and salt component or brine volume, using evaporation to ensure that the water going back was not contributing to the sludge, without paying any attention to the wasted/disposal portions. As EPA and other international agencies started paying attention to the environmental factors, the larger benevolence and reusability of the solid waste, as well as rather expensive pure water, removal of contaminants and higher durability of good quality membrane used in de-mineralisation were some of the factors that came under consideration.

Many pre-treatment technologies have been derived depending on the quality and contents of the PW, the geological and physiological aspects of the water source, and the usage of the treated water and the pre-treatment technologies are suitably decided.

As per the US Environmental Protection Agency (EPA) waste management or reutilisation requirement, it is advisable that all inert and non-hazardous wastes are pre-treated before disposal or further processing. In case of hydrocarbon waste and hazardous disposal it is important to connect with relevant recycling units and waste disposal centres to ensure wastes are recycled appropriately and hazardous wastes are disposed via proper procedure.

**Centralised Waste treatment (CWT) facilities can accept oil and gas extraction waste water**




*Source: www.epa.gov*

## ION EXCHANGE (IE)

Ion exchange is one of the significant processes known in water treatment methods where a non-affecting element is induced to propagate an IE of some pollutants and undesirable elements from the fluid/water via electoral charge. IE is a process which is used very effectively in treatment of drinking water.

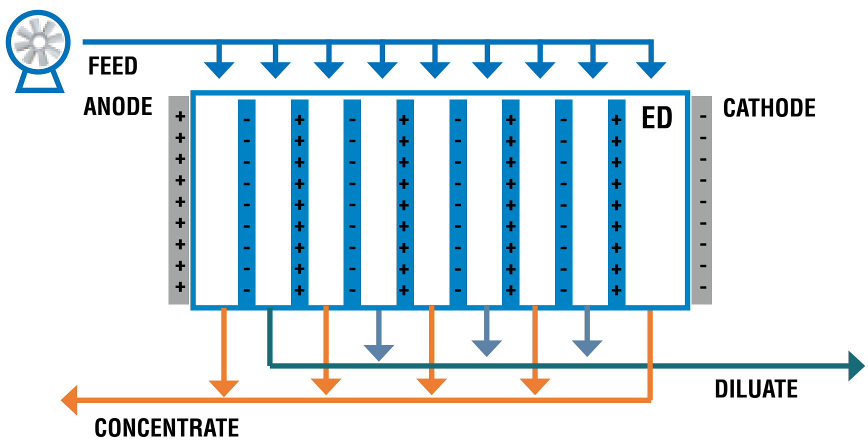
## MEMBRANE PROCESSES

In the traditional use of the membrane process in well fluid and PW treatment there are in-depth R&D being done to ensure the health and quality of the membrane in order to maintain the pressure range to be used in re-injection wells. The use of membrane technology for the produced and refinery waste water treatment has been rather recent and technological research has happened to enhance the efficiency and life time of the membrane, focusing on various membrane technologies starting from microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO).

To augment the environmentally beneficial aspects, two significant technologies that are being focused on are membrane distillation (MD) in combination with forward osmosis (FO).

## ELECTRODEIONISATION (EDI)

Argonne National Laboratory has developed a process called Resin-Wafer Electrodeionisation (RW-EDI) that uses a porous immobilised loose ion-exchange resin beads referred as resin wafers for desalination of brackish water (ref. Argonne National Laboratory website). Conventionally applied water purification technologies of electro-dialysis and ion exchange are not sufficient for the purity requirement or cost effectiveness in purifying volumes of water. Also, the ion exchange process needs chemical reagents for its application. Need for an advanced technology that could be faster, continuous and cost effective came about known as ElectroDeIonisation (EDI) that combined Faraday's conventional eletro-dialysis method of using electrodes to separate dissolved ions and resin membranes to separate solids and liquids to achieve high purity of water. The RO system used for EDI is considerably better and different for it is done without any chemical intervention. Subsequently the cost, speed, and purity of the technologies are optimised by devising the CEDI (continuous electrodeionisation) technology that continuously regenerates the resin mass effective for ionisation. Moreover, since there is no application



of chemicals, EDI is considered green for the environment.

As a promising new technology, hydrocarbon EDI and RWEDI technologies were proven by EPA as suitable in treating the water from the aquifers that seals the methane within the coal formation (CBM). Inability to remove and dispose of the water from such aquifers suitably affected restoration of such gas since a long time. The PW volume, pressure, and contaminants varies during the entire phase of the production yet contains very high TDS and at times very low organic content, TSS and heavy metals are usually very low. Treatment objectives are to reuse the water or make the water acceptable by reducing waste and hazards for landfill discharge and agricultural use.

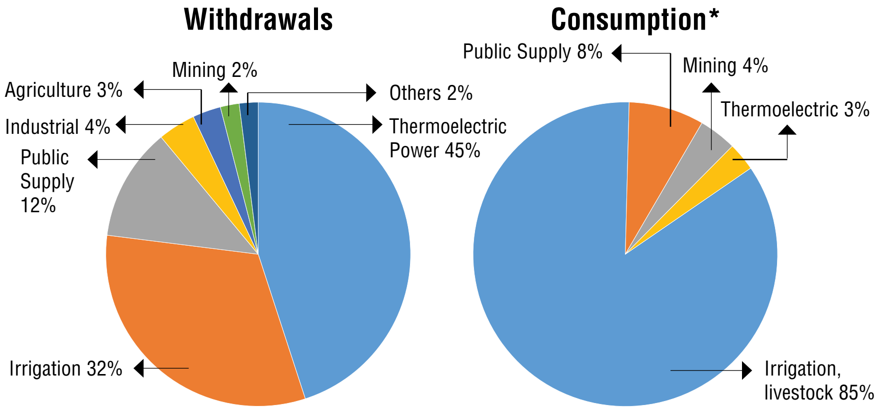
## WASTEWATER RECYCLE/REUSE

Interestingly, only 2.5 percent of the world's water is fresh. Until quite recently, across the world freshwater was made available for free. Unfortunately, this is still a fact in many countries including India where freshwater has been used not merely for drinking but for most of the daily consumption requirements. What's more, reusing of water via basic or proper treatment and disposing waste appropriately to ensure the freshwater sources are not contaminated, are still a distant reality.

In case of hydrocarbons, most aged oilfield countries including India have been using conventional methods for treating the PW. Even in cases of enhanced oil recovery from work-over-wells or simply asset recovery using polymer injection, most national hydrocarbon companies especially have remained with basic water filtration through tank-based chemical applications.

Despite the fact that polymer injection is a modern technology, the same might not be the ideal solution as the emulsion gets very sludgy and contaminants are not suitable for disposal within the government approved stipulations. Hence

### INDUSTRY WATER USE




*Source: US Geological Survey as referred by Paula Dittrick in Oil & Gas Journal dated 08/07/2017)*

the exploration and production (E&P) companies pay very high penalties. The critical requirements are to ensure:

1. Water secured from PW is treated for reuse most effectively; and
2. Disposals including hazardous disposals are suitably treated to comply with the environmental norms.

### Refinery water – reuse and disposal

According to Tom Schultz, Oil and Gas Market Director for Siemens Water Technologies, 'How much water you use depends on each facility. A 100,000 bpd refinery might use between 100,000 to 200,000 bpd of water.' It is pertinent to understand that refineries already receive sludgy PW that must go through the entire pre-treatment process in order to be suitable for refining. Additionally, it uses huge amounts of water for de-brining the crude it receives from the pipelines, to be used in the steam boilers as well as in its cooling towers for condensation, where almost 50 percent gets evaporated as steam but the rest is ready for disposal. The disposable oily water usually is not suitable for the landfills and hence government has imposed strict stipulations to ensure proper and adequate treatment of the water before being disposed.

Water technologists are considering such challenges as opportunities to investigate ways to appropriately reuse the disposals and eliminating the hazardous elements.

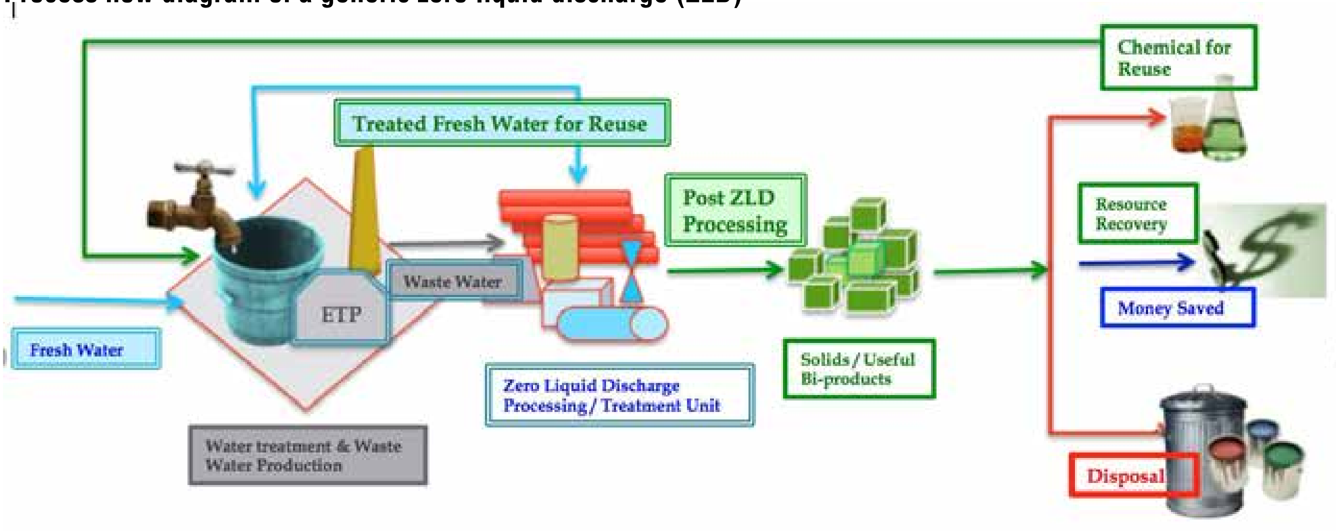
## DESALINATION

'Once upon a time, the acquisition and disposal of water in the refinery and petrochemical sectors used to be a relatively minor issue. If it is cheaper to buy water from a municipality and dispose of salty water in an injection well, then that is what an oil company will do,' said Edward Godeaux, Technical Director with Siemens Water Technologies.

Desalination is not only an advanced EDI process using membrane via RO and thermal process of steam evaporation of salt water and condensation of pure water; it is one of the most effective and adopted water treatment processes in reusing brine water or seawater by the removal of the salt component. With governments across the world implementing stricter legislations as well as the high cost of water due to the growing demand and unavailability of fresh or reusable water, it is becoming really important to discover new technologies and review the available ones to provide for water resources – both for industrial as well as municipal usage.

Said Henri Inselberg, Vice President,

## Process flow diagram of a generic zero liquid discharge (ZLD)




Sales and Contracts, for IDE Technologies Ltd: 'I am very optimistic about the future of desalination. You can clean water up, or find new sources. The only new source left is seawater.'

### ZERO LIQUID DISCHARGE (ZLD)

*Although the history of tighter regulations on wastewater discharge can be traced back to the US Government's Clean Water Act of 1972, India and China have been leading the drive for zero liquid discharge regulations in the last decade. Due to heavy contamination of numerous important rivers by industrial wastewater, both countries have created regulations that require zero liquid discharge. They identified that the best means to ensure safe water supplies for the future is to protect rivers and lakes from pollution.*
As sourced from an academic article at: https://www.saltworkstech.com

The ZLD system or achieving ZLD, ensuring 100 percent water recovery, helps industry in reducing the cost of water in the production system as well as adherence to the stringent government stipulations. The process at times also yields various precious solid components like potassium sulphate, sodium sulphate, gypsum, lithium, etc. In fact, the lithium solid yield from the desalination process as part of the ZLD system made a revolutionary discovery possible for PurLucid, Canada, of a patented technology to produce lithium really fast, as well as enabling ZLD systems to employ the most advanced wastewater treatment technologies to purify and recycle virtually all of the wastewater produced.

As explicit in the process flow diagram, ZLD is a possible yet difficult to achieve engineering process where there is practically 'zero' discharge or waste of water with 100 percent recovery as fresh reusable water and disposals are transformed to solid state. Obviously, the challenges to achieve a zero discharge target gets difficult with the increase in volume of fresh water recovery from PW that gets more and more concentrated with the removal of fresh water since with such a removal the disposable remnants get thicker and more sludgy with contaminants and oily coagulants. ZLD is achieved by first of all evaluating the content of the treatable PW and defining/pilot testing the possible solutions and thereby stringing together water treatment technologies that can successfully treat hardened, sludgy wastewater and relevant concentrated contaminants.

### Hazardous waste in hydrocarbon

The Resource Conservation and Recovery Act (RCRA) regulation defines hazardous waste as a solid waste, or combination of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may (a) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

As per the EPA's definition of hazardous waste, the following four determinants of hydrocarbon wastes post treatment tend to have significant hazardous constituent:
• Ignitable or something that's flammable (any form of petroleum/carbon traces)
• Corrosive or substance that could rust or decompose (Water-tank bottom corrosions are common)
• Reactive or something explosive (reactive surely for any exposure to fire or air)
• Toxic, or something poisonous (several

An oiled brown pelican near Grand Isle, Louisiana

Oil stained beaches in Pensacola, Florida; 1July 2010

including CO discharge to be a frequent phenomena).

April 2010 saw one of the world's worst oil disasters due to two very tiny leaks in the deep water production pipeline of BP that went unnoticed and caused considerable leakage over to create the worst fire around the Louisiana bay in the USA and leading to massive environmental loss and irreparable damage. Oil regulatory bodies such as RCRA and EPA and similar others across the world stepped in to get industries or hydrocarbon producing companies to take onus for their production processes as well as environmental protection assurance by ensuring protection of the resources involved and implementation of appropriate waste disposal methodologies.

Additionally, the Quality Health Security Environment (QHSE) function in corporates, especially hydrocarbon companies, has taken the shape of an operational function tied to deliverables from employees across the board; they are mandated to take ethical and duty-bound responsibilities to adhere to environmental procedures and significant rules. For hydrocarbon companies, RCRA mandates hazardous waste disposals handled as a significant function to be auditable as part of the annual financial report audits.

The RCRA and the Atomic Energy Act have defined waste that has a hazardous component and a radioactive component as mixed waste that must be regulated. Similarly in India, in April 2017, the Supreme Court set 31 March 2019 as the new deadline for all the sewage treatment plants and common effluent treatment plants to meet the water quality norms set by the pollution control boards. Flouting norms and stipulation as per order is an indictable offence, leading to closure notice along with civil and criminal proceedings.

Across the world, all hydrocarbon production companies including refineries and hydrocarbon by-product user industries are required to install ETP or wastewater treatment plants and disposal management in order to adhere to the environmental norms for production and waste management.

## ETP or effluent treatment process

Effluent Treatment Plants are used for treating water from effluents. Used mainly for industrial effluents, ETP relates to separating sludgy wastes from the hydrocarbon produce. Typically, effluent being treated is sludgy substance composed of water, residual product, and various solids including sand, scale, and rust. The significant processes of filtration applications in hydrocarbon – such as brine from completion fluid filtration, polishing filters for injection water, and even difficult yet critical produced or oily water treatment for re-injection – are improving constantly, getting smarter and better at separation technologies given the growing environmental consciousness and even stricter regulations. The treated condensate and crude oil from the separators are stored in tanks and are moved to refineries via tankers and pipelines for further processing and refinement to by-products like petroleum naphtha, gasoline, diesel, asphalt base, and kerosene. At this juncture the wastewater from refining of the crude is disposed mostly in landfills or evaporated to separate from solid wastes.

## ETP regulations

During the entire production and distribution process of the hydrocarbon value chain, there are many challenges in terms of waste management as well as environmental health due to leaks, spills, and operation-induced contamination with sludgy, hazardous, and even radioactive substances, requiring detailed treatment and careful handling or disposal of the residual wastes. Serious concerns like tank

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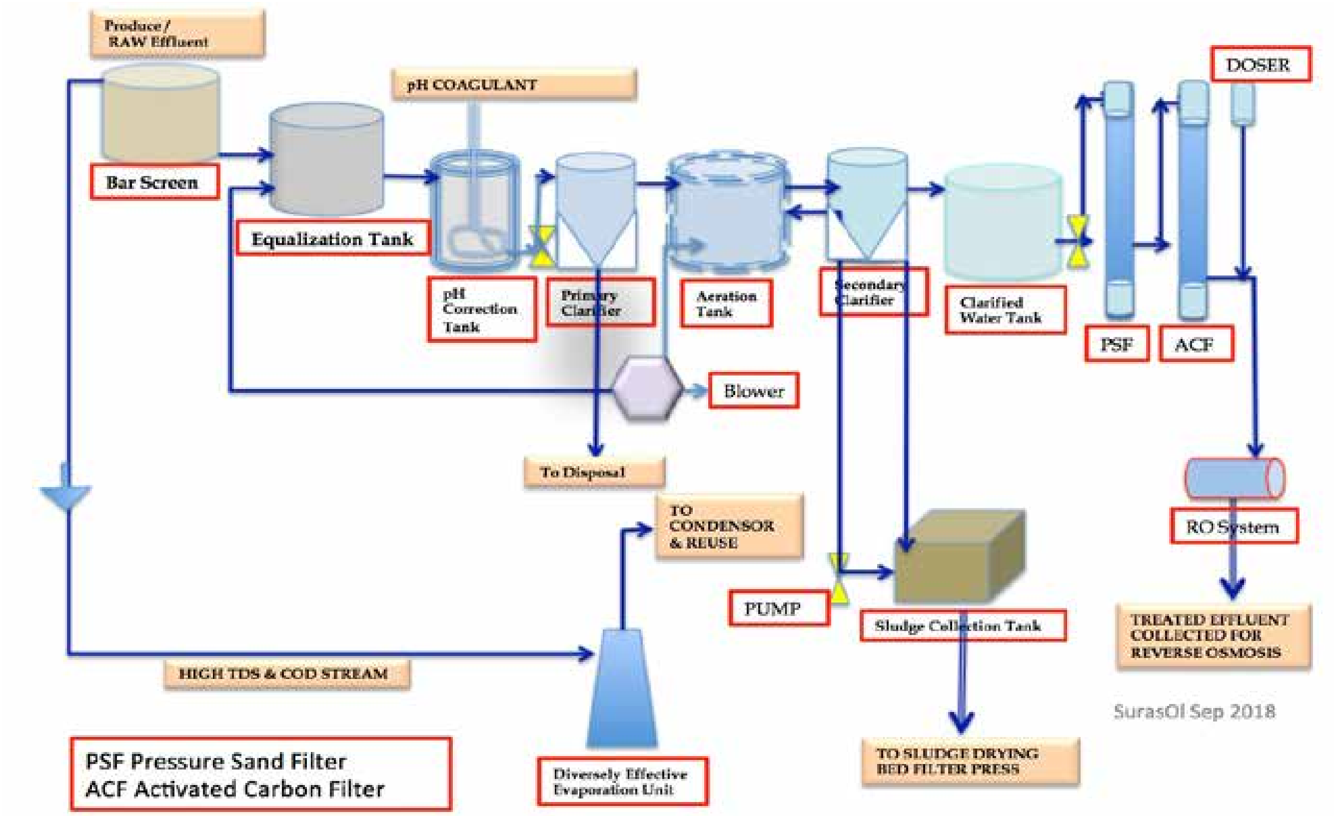
## Flow diagram of general effluent treatment process




bottom sludge, rusting on the walls of the tank/pipelines must be removed and treated to ensure oil at collection, storage, and distribution through pipelines until the doors of refineries maintain expected quality. During distribution, spillage and soil require careful cleaning. New technologies like the plasma gasification process is designed and engineered to ensure efficient energy recovery from wastes.

Today, many water and hydrocarbon technology companies have acquired successful proven track record in implementing all-round waste and water treatment solutions. Filtration of these fluids requires sophisticated technological solutions both in treatment and filtration, which have been discussed briefly here.

The ETP processes especially for hydrocarbon operation streams are as varied as the volume of produce the specific system is supposed to treat and at the specific stream the produce belongs to – upstream, midstream or downstream – and depending on the state the crude is at. Interestingly, the waste treatment too needs specific attention to the chemical components of the fluids post separation. Depending on the components, the waste that is released from treatment requires specific attention on disposal.

### Sweeter truth – sweet crude

As reiterated across the document, it is not necessarily all is crude. There are sweeter truths in the whole concept of oil and gas value chain. Refined crude oil by-products like petroleum jelly is even used in beauty products and medicines. However, simply from the drilled produce crude oil, there are crude oils that are refined to use gasoline and are usually highly priced and in extremely high demand known as light crude oil (LCO) These contain smaller amounts of hydrogen sulphide, sulphur and carbon dioxide and are known as sweet crude oil, whereas crude containing higher sulphur is called sour crude oil.

Brent crude oil produced in Europe from Northwest-Sea and WTI (West Texas Intermediate) are considered 'light' or 'sweet' crude and used for determining international oil prices whereas Saudi Arabian crude oil is considered 'sour.'

Despite the sweetness, all crudes are required to go through detailed treatment procedure and follow stringent environmental safety rules to be followed mandatorily in order to maintain the resourcefulness of the 'water' from the produce or hydrocarbon fluids.