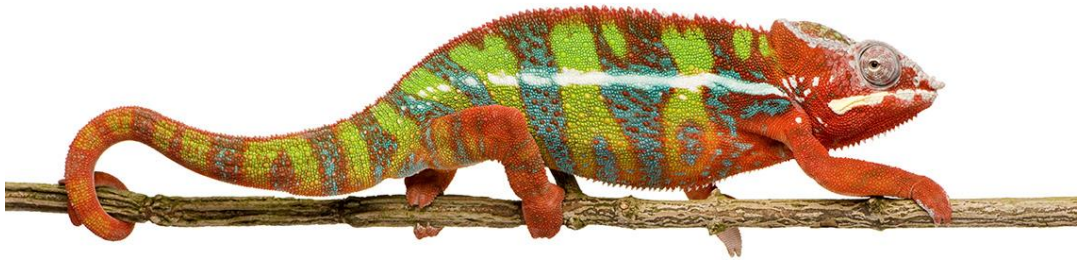
Water and Waste-Water Treatment for Oil and Gas

Rami Elias Kremesti M.Sc., CSci, CEnv, CWEM

KREMESTI ENVIRONMENTAL CONSULTING



PASSION FOR CHEMISTRY

Types of Petroleum Oil/Gas

- Heavy crude oil, tight oil (oil found in impermeable shale and limestone rock deposits), oil sands and shale oil (a sedimentary rock impregnated with oil).
- Biogas - Methane
- Sour Biogas – Methane, Ethane and H_2S
- Shale Gas

Upstream vs Midstream vs Downstream

- Upstream is oil and gas extraction including fracking
- Midstream is oil and gas storage and transfer
- Downstream is oil and gas processing/refining

Basic Process Goals

- Separate Suspended Solids, Dissolved Solids, Oils, Gas and Water
- Recover Oil/Gas
- Purify Water for Reuse
- Cyclical Process (Circular Economy)
- Protect the Environment and Human Health/Safety
- Recover Sour Gas H_2S to produce sulfuric acid (H_2SO_4)
- Separate oil into lighter liquids (biogas, petrol, diesel, kerosene) and heavier liquids for lubrication
- Prevent corrosion due to salinity

Basic Processes/Principles

- Gravity separates solids and oils from water (three layers form)
- Centrifugation assists gravity separation using G-forces
- Filter presses help dewater sludges
- Active Carbon Filters and Walnut Shell filters help remove dissolved solids from waste-water that has been treated in an Oil Water Separator
- Temperature in the form of heat can help solids/oil and water to separate
- Crackers and Fractionation Columns require steam
- To produce steam you need ultra-pure desalinated water

Chemicals Used

- Emulsion Breakers
- Viscosity adjusters
- Corrosion Inhibitors
- pH adjusters
- Anti-scalants
- Flotation/settling coagulants/flocculants
- Biocides to kill bacteria/biofilm

Waste-Water Collection

- Waste water from refining processes is frequently collected in lagoons or waste water ponds. The viscosity of the waste in these ponds can vary considerably dependent upon the water, oil and solid content.
- There is a rule of thumb that for every barrel of oil extracted, 7 barrels of produced water are created which needs treatment before re-use.

1st Step: Decanters

Decanters Reduce disposal costs and recover oil residues

Decanters represent an ideal technology for treating waste water. The decanters reliably separate oil and fine sediments from the waste water, enabling the recovery of valuable oil residues, which also increases profitability. Reduced volumes of waste water means lower disposal costs, and decanters adapt automatically to fluctuating feed conditions, so can achieve optimal results, even when the solids concentration of the waste water changes.

Sample Decanter from GEA

4th Step: Slop Oil Treatment

- Slop oil or waste oil is frequently stored in oil lagoons and is obtained in the course of cleaning oil tanks, in filter backwash processes, as a waste product of the refining process, by way of leaks or "rejects" - waste from traditional oil treatment installations.
- They are mixtures of oil, a wide range of chemicals, water as well as coarse and fine solid particles, whereby there can be a major variation in the various compositions.
- Slop oil can be separated from the admixed solids and water and recovered as valuable product.

Pre-treatment of Slop Oil

- The oil temperature is raised to process temperature, chemicals (e.g. demulsifiers) are added for splitting emulsions, so that it can subsequently be homogenized in special mixers. This is an important aspect to ensure that the entire process is kept as stable as possible. Irrespective of whether the mixture has a high water and solids content or whether it has a high viscosity – high-performance decanters separate the solids; if used as three-phase decanters, they simultaneously separate the water from the oil, too. **Decanters** automatically adapt the differential speed to the fluctuating feed conditions to always provide the best separation efficiency. In the subsequent polishing stage, **disk-type centrifuges** separate the residual water and extremely fine particles from the oil. The recovered oil now complies with the standard refining requirements and can be mixed with normal crude oil for further processing.
- The processing of the aqueous phase from the decanter is handled by self-cleaning disk-type separators. They "polish" the water by removing extremely fine sediments and by reducing the residual oil content to the permissible limit and even below (usually 15 ppm and lower). In this way, existing environmental protection requirements can be reliably met, and the water can be disposed of in an environmentally friendly manner.

2nd Step: High performance oil separators for clean water

- Downstream of decanter treatment, high-performance oil separators can be applied to treat the aqueous phase that is still contaminated with oil. Separators ensure that a residual oil content of less than 15 ppm is achieved in the aqueous phase, to meet regulatory environmental requirements.
- The American Petroleum Institute (API) has standards for design
- Oil separators recover the water and oil and any sludge from the bottom is scraped and filter pressed to extract residual oil.

A Centrifuge Oil/Water Separator from GEA

Centrifuge Oil/Water Separators

- Oil & Gas separators come in gas-tight design with nitrogen blanketing for reliable explosion protection (ATEX), for maximum protection and uptime of separators which normally use duplex/ super duplex steel as bowl material. Constant movements on platforms are compensated so that the centrifuges are perfect for onshore as well as offshore installation.
- Centrifuges accelerate the gravity process by applying higher G forces

Separating oil and water phases, purifying emulsions, removing **cat** (catalyst) fines:

- The requirements and procedures for processing crude oil, slop oil and other solid-liquid mixtures are fundamentally different. In all applications, separation process technology is used throughout the world on drilling platforms and FPSOs (floating production storage and offloading ships) in the Atlantic as well as in the oil sand mines in Canada, and for refineries throughout the world.
- A floating production storage and offloading (FPSO) unit is a floating vessel used by the offshore oil and gas industry for the production and processing of hydrocarbons, and for the storage of petroleum oil.

4th Step: Removing Sour Gas (H_2S)

- Stripping H_2S is necessary because this noxious gas is dangerous and can form H_2SO_4 if oxidized in the refinery which is a corrosive chemical
- Stripping of H_2S can be done using Nitrogen gas (from suppliers such as Air Products or Air Liquide) or membrane technology
- The H_2S can be recovered to produce H_2SO_4 which is an industrial chemical.

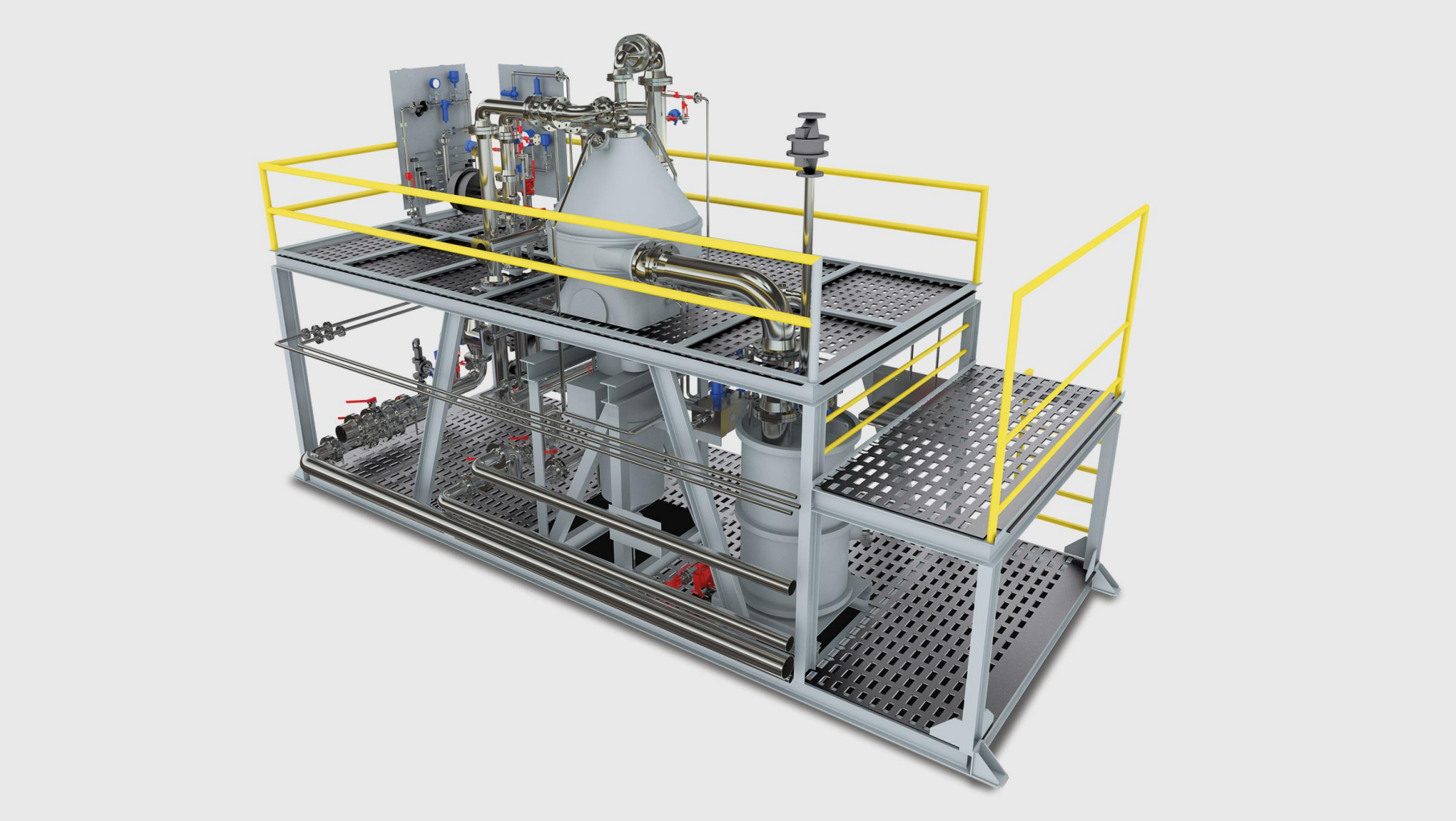
5th Step: FCC SLURRIES

- Modern refineries use the **fluid catalytic cracking (FCC)** process, which converts residual petroleum products into more valuable gasoline, diesel fuel and gas oil in atmospheric and vacuum distillation units at refineries. In this case, long chain hydrocarbons are cleaved using aluminium and silicon-based catalysts, the particles of which are submicron in size. Slurries are created in the process.

6th Step: CRUDE OIL/WATER DESALTING

- Raw crude oil contains water, salts and other contaminants. If these salts and heavy metals are not removed, they can form acids when heated, causing corrosion of downstream process equipment. Salts can also form deposits, causing plugging of heat exchangers or clogging trays in process towers.
- Extracted Crude oil comes out mixed with the extraction water (Produced Water) and these need to be separated. The water in the process becomes more saline and sometimes the TDS needs to be lowered otherwise this can lead to corrosion of steel pipes.
- For desalinating waste-water, either evaporation or RO is used

Water Removal/DESALTING System



Produced Water Treatment

- The term Produced Water is used in a description of water that is produced as by-product during the extraction of oil and gas. It is a mixture of organic and inorganic compounds and treatment of Produced Water can be challenging due to large variations of its contamination.

  The general objective is to the contaminants by applying physical, chemical and biological treatment before Produced Water can be released back to water recirculation, re use or simply discharged back to nature.

MBBR + Ozone For Produced Water Treatment

- One technology used with the treatment of Produced Water is MeteorTM - the SUEZ MBBR solution based on biological treatment - and OxyblueTM, which is a solution based ozonation for chemical oxidation of hardly biodegradable substances.

Ceramic (SiC) Membranes

- The LiqTech oil and gas filtration systems offer guaranteed filtration performance under challenging conditions. Typical operating performance is treated water with TSS and OiW concentrations well below 5 mg/L and efficient removal of particles larger than 0.1 micron.
- The core technology of the oil filtration system is the LiqTech patented silicon carbide (SiC) ceramic membrane technology. A very robust material with a high filtration efficiency compared to conventional filters and alternative membrane materials.

Nut-Shell Filter

- A nut-shell filter is a device to remove oil from water. In the oil & gas industry, the term walnut shell filter is common since black walnuts are most often used.
- Typically nut-shell filters are designed for loadings under 100 mg/L oil and 100 mg/L suspended solids and operate with 90–95% removal efficiency. High oil and solids loadings reduce run times between backwashes and results in reduced effluent quality.

7th Step: Vacuum Distillation

- After the preliminary treatment steps, crude oil is distilled into fractions using VACUUM DISTILLATION COLUMNS where diesel, kerosene and petrol are separated from the heavier fractions.
- Different fractions in the pre-treated crude oil have different boiling points and this is the principle used for separation

Oil Refinery Which Uses Heat and Vacuum

8th Step: Refineries Need Steam hence Boilers

- Boilers produce the steam that is needed in refineries
- Ultra-pure desalinated water is needed to create pure steam
- For this careful boiler chemistry control is needed
- Scale/deposits and corrosion are the main culprits
- There are fuel oil burning boilers and biogas burning boilers which are cleaner
- Ideally the CO_2 produced in the combustion furnaces is captured using CCS

9th Step: Refineries need Cooling Towers

- Wherever steam is produced, the condensate needs to be cooled using heat exchangers and cooling towers that shed the heat
- Cooling tower chemistry/microbiology focuses on 5 main issues:
  - Scaling
  - Fouling
  - Biofouling: bacteria and algae
  - TDS removal: dissolved solids
  - Corrosion

Equipment Suppliers

- Veolia
- GEA
- Sulzer
- WesTech
- Evoqua
- SPX – Cooling Towers
- Spirax Sarco
- Atlas Copco
- ALSTOM/GE
- Babcock

Technip

WesTech
Process Equipment. Process Driven.

GEA Engineering for a better world.

VEOLIA

ANDRITZ

evoqua

SULZER

Atlas Copco

SPX
COOLING TECHNOLOGIES

Refinery Process Monitoring

- Refinery process monitoring is a complex subject and involves the monitoring of Pressure, Temperature, Mass/Flow, Conductivity, Chemistry, Vacuum, Condensation Points, Vibration etc.
- Complex PLC's/SCADA systems are needed for data logging and safety interlocks

Lab Testing

- Various tests are used in Downstream Refineries for checking the quality of product fuels and other heavier products.
- Physico/Chemical Tests are also needed for monitoring Boilers
- Physico/Chemical and Microbiological Tests are needed for monitoring Cooling Towers and waste-water.
- Health Monitoring is also needed to monitor dangerous substances in the air to make sure their safe levels are not exceeded.

References

- https://www.gea.com/en/oil-gas-energy/downstream/index.jsp
- Veolia: https://www.watertechnologies.com/products/oil-gas-engineered-systems/oil-gas-water-treatment
- https://www.sulzer.com/en/shared/applications/refining-crude-oil-desalting-process
- https://www.worldofchemicals.com/721/chemistry-articles/chemicals-used-in-crude-oil-production.html
- https://www.westech-inc.com/products/oil-water-separator
- https://www.atlascopco.com/en-uk/rental/resources/blog/removal-of-h2s-via-crude-oil-stripping

References - II

- https://www.aiche.org/chenected/2011/11/produced-water-treatment-ceramic-membranes
- https://liqtech.com/ceramic-membranes-dpf/silicon-carbide-ceramic-membrane/
- https://en.wikipedia.org/wiki/Nut_shell_filter
- https://www.suez.com/en/denmark/produced-water-treatment-for-industrial-wastewater