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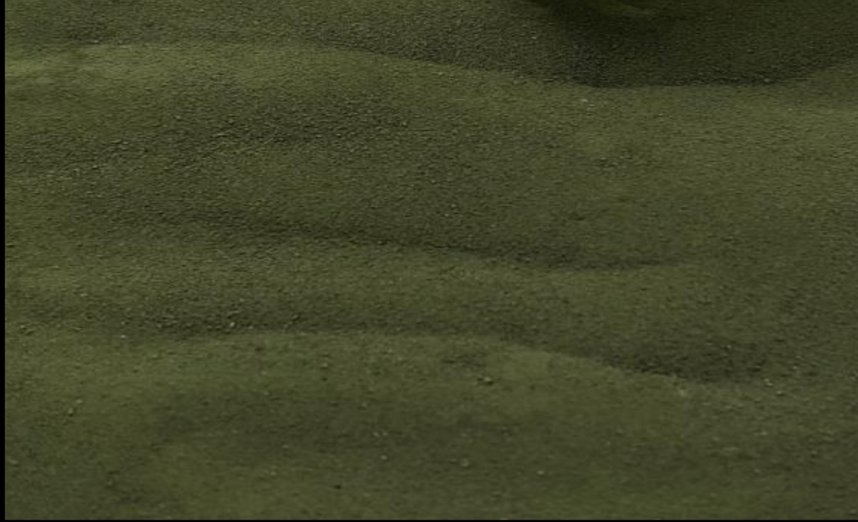

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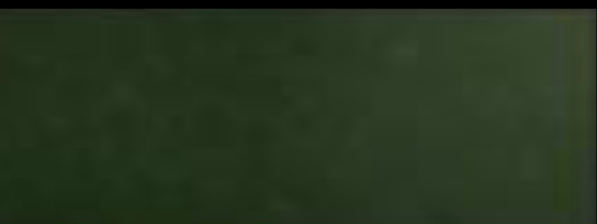

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Closing the Sustainability Cycle: The Role of Plastics Recycling Technologies in the Future of Downstream Industry

Dr. Marcio Wagner da Silva

INTRODUCTION AND CONTEXT

According to recent forecasts, the petrochemical market tends to rise in the next years and, in middle term, will be responsible by a major part of the crude oil consumption over passing the transportation fuels this fact have been made the refiners to looking for closer integration with petrochemical assets through the maximization of petrochemical intermediates in their refining hardware as a strategy to ensure better refining margins and higher value addition to the crude oil. Figure 1 present an overview of the trend of growing to the petrochemical market in middle term.

Some markets already are facing with the gasoline surplus, in these cases, directing naphtha to petrochemicals against gasoline can be an attractive way to ensure competitiveness to refiners. Figure 2 present the evolution of gasoline surplus in the Russian domestic market, as an example.

Again, being a high demand and most profitable market, the alternative to convert naphtha to petrochemicals should be a trend to refiners inserted in markets with gasoline surplus in the next years. According to data from Wood Mackenzie Company (2021), the highly integrated refiners can add from US$ 0,68 to US$ 2,02/ bbl. Still according to Wood Mackenzie, the Asian Market presents the major concentration of integrated refining plants.

As presented in Figure 3, the petrochemicals demand tends to drive the crude oil demand for the next years.

This fact tends to restrict the consumer market which tends to offer lower refining margins, another great advantage to refiners capable to convert naphtha to petrochemicals against gasoline.

Additionally, it’s important to quote that the gasoline demand will be sustained by the in developing economies, as presented in Figure 4.

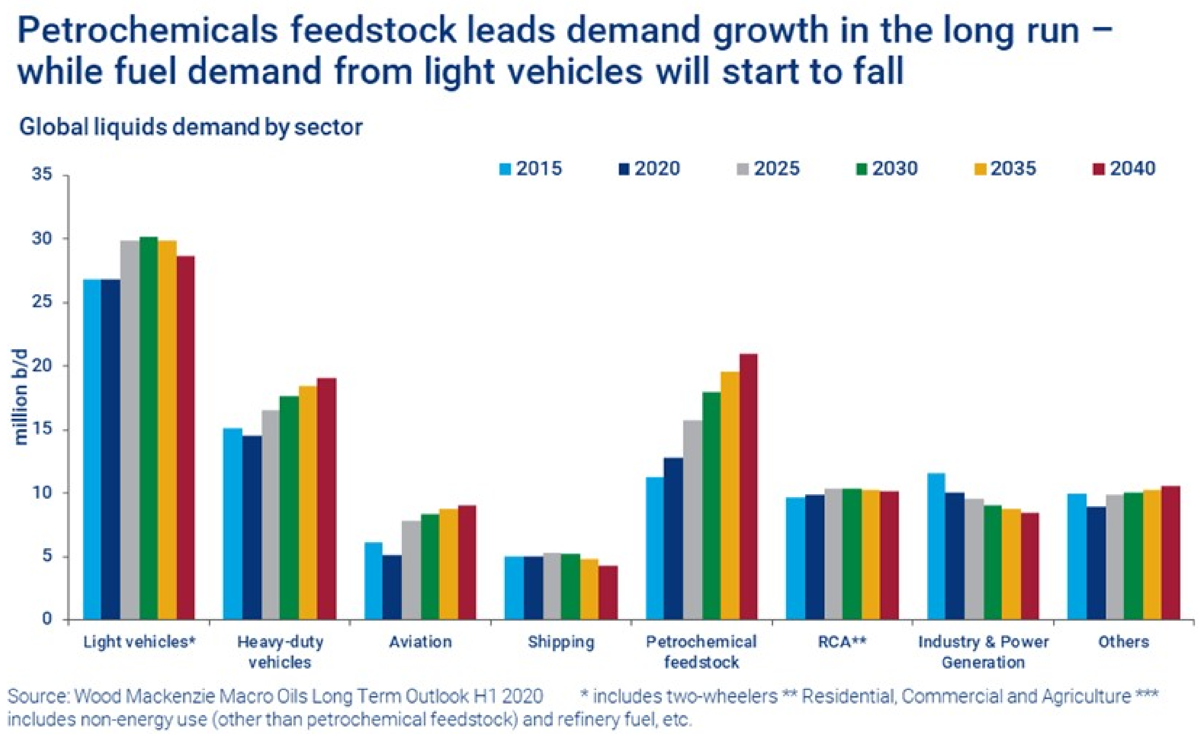

Figure 1 – Growing Trend in the Demand by Petrochemical Intermediates (Wood Mackenzie, 2020)

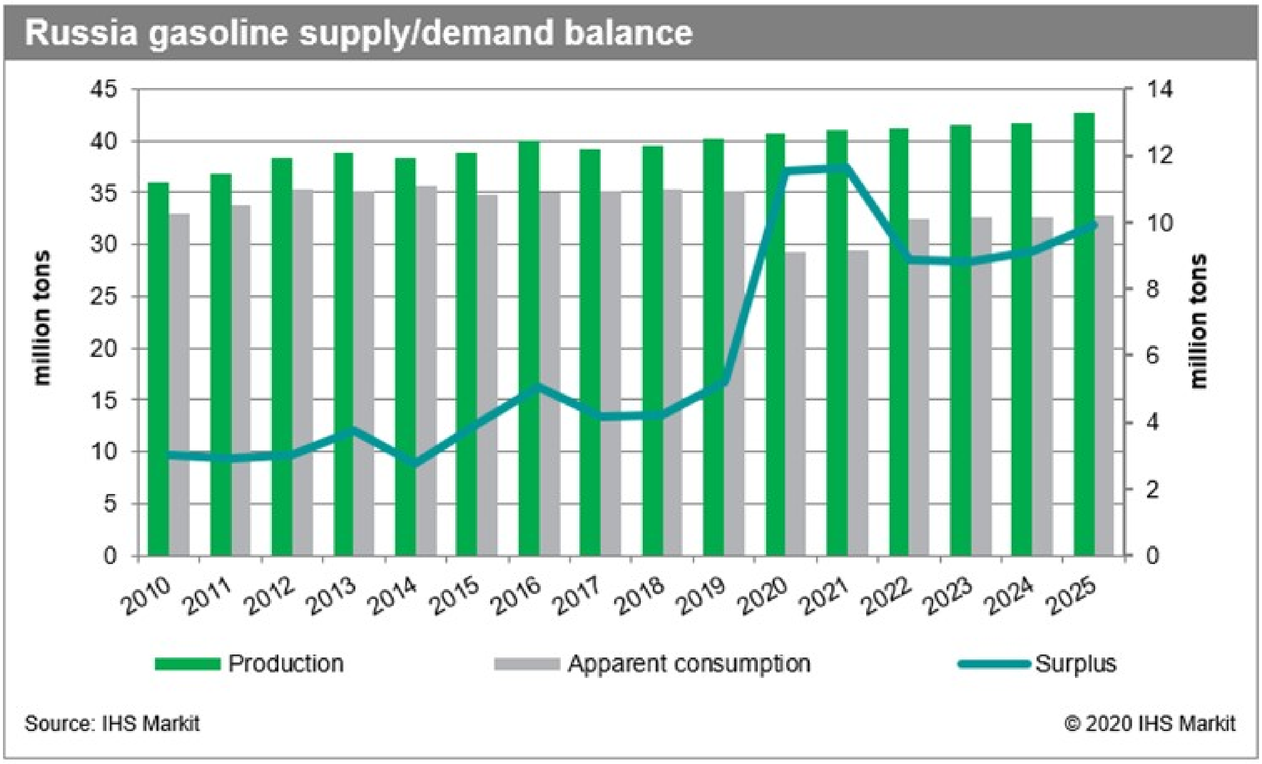

Figure 2 – Evolution of Gasoline Surplus to the Russian Domestic Market (IHS Markit, 2020)

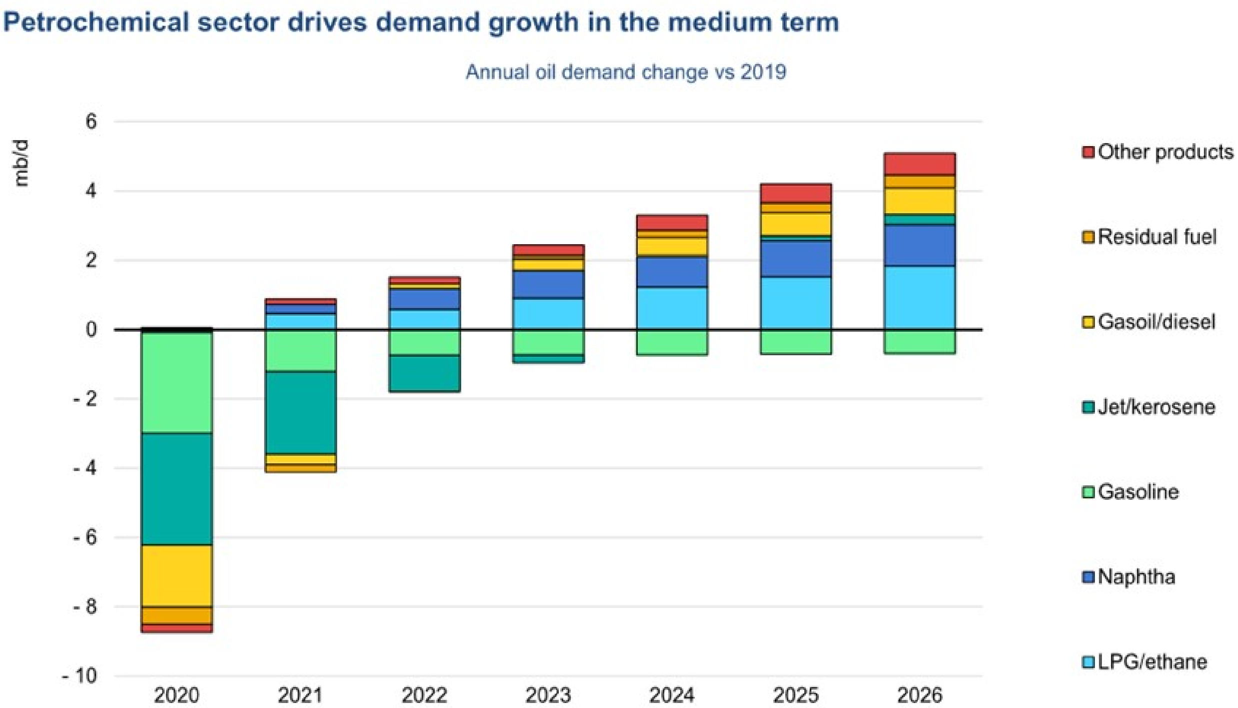

Figure 3 – Growth of Petrochemicals as Driver for Crude Oil Consumption (IEA, 2021)

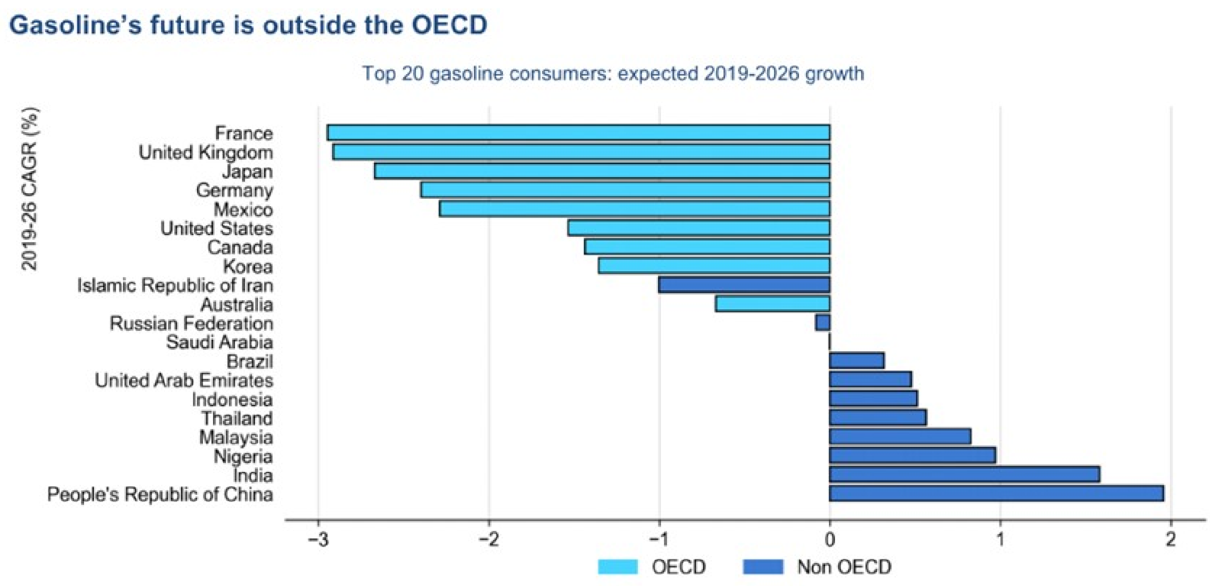

Figure 4 – Growth of Gasoline Demand for the Next Years (IEA, 2021)

Based on description above it's possible to apply the article published by W. Chan Kim and Renée Mauborge called "Blue Ocean Strategy" in Harvard Business Review, to classify the competitive markets in the downstream industry. In this article the authors define the conventional market as a red ocean where the players tend to compete in the existing market focusing on defeat competitors through the exploration of existing demand, leading to low differentiation and low profitability. The blue ocean is characterized by look for space in non-explored (or few explored markets), creating and developing new demands and reaching differentiation, this model can be applied (with some specificities once is a commodity market) to the downstream industry, considering the traditional transportation fuels refineries and the petrochemical sector.

Due his characteristics, the transportation fuels market can be imagined like the red ocean, where the margins tend to be low and under high competition between the players with low differentiation capacity. On the other side the petrochemicals sector can be faced like the blue ocean where few players are able to meet the market in competitive conditions, higher refining margins, and significant differentiation in relation to refiners dedicated to transportation fuels market. Figure 5 present the basic concept of blue ocean strategy in comparison with the traditional red ocean where the players fight to market share with low margins.

As presented above, the market forecasts indicates that the refiners able to maximize petrochemicals against transportation fuels can achieve highlighted economic performance in short term, in this sense, the crude oil to chemicals technologies can offer even more competitive advantage to the refiners with capacity of capital investment.

Can be difficult to some people to understand the term "differentiation" in the downstream industry once this is a market that deal with commodities, but the differentiation here is related to the capacity to reach more added value to the processed crude oil and, as presented above, nowadays this is translated in the capacity to maximize the petrochemicals yield, creating differentiation between integrated and non-integrated players.

MAXIMIZING ADDED VALUE TO THE PROCESSED CRUDE – PETROCHEMICAL INTEGRATION

The focus of the closer integration between refining and petrochemical industries is to promote and seize the synergies existing opportunities between both downstream sectors to generate value to the whole crude oil production chain. Table 1 presents the main characteristics of the refining and petrochemical industry and the synergies potential.

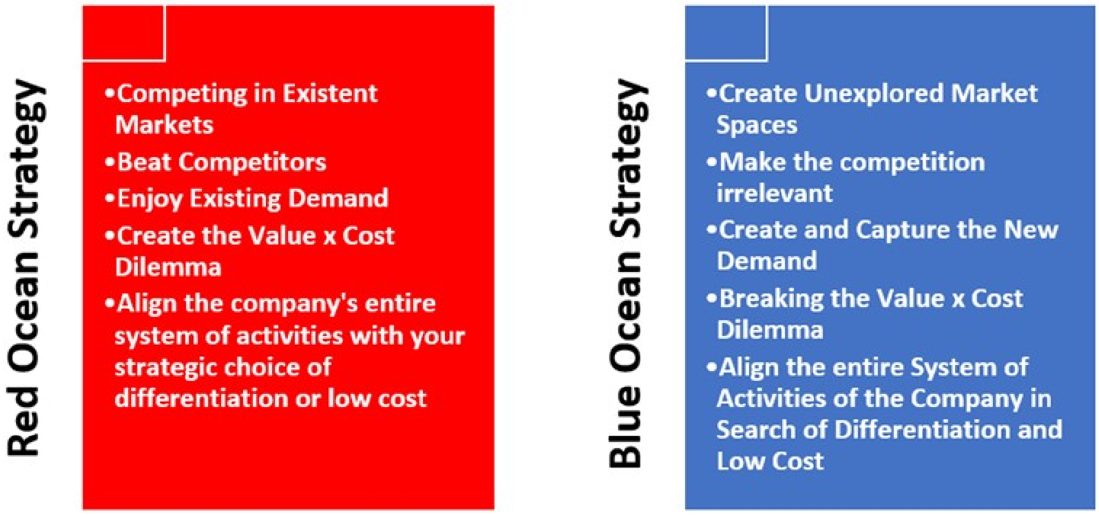

Figure 5 – Differences between Blue and Red Ocean Strategies (KIM & MAUBORGNE, 2004)

As aforementioned, the petrochemical industry has been growing at considerably higher rates when compared with the transportation fuels market in the last years, additionally, represent a noblest destiny and less environmental aggressive to crude oil derivatives. The technological bases of the refining and petrochemical industries are similar which lead to possibilities of synergies capable to reduce operational costs and add value to derivatives produced in the refineries.

Figure 6 presents a block diagram that shows some integration possibilities between refining processes and the petrochemical industry.

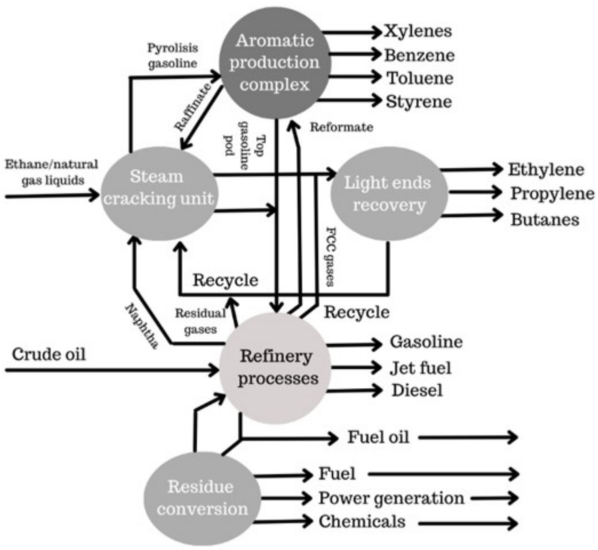

Figure 6 – Synergies between Refining and Petro chemical Processes

Refining Industry	Petrochemical Industry
Large Feedstock Flexibility	Raw Material from Naphtha/NGL
High Capacities	Higher Operation Margins
Self Sufficient in Power/Steam	High Electricity Consumption
High Hydrogen Consumption	High Availability of Hydrogen
Streams with low added Value (Unsaturated Gases & C2)	Streams with Low Added Value (Heavy Aromatics, Pyrolysis Gasoline, C4's)
Strict Regulations (Benzene in Gasoline, etc.)	Strict Specifications (Hard Separation Processes)
Transportation Fuels Demand in Declining at Global Level	High Demand Products

Table 1 – Refining and Petrochemical Industry Characteristics

Process streams considered with low added value to refiners like fuel gas (C2) are attractive raw materials to the petrochemical industry, as well as streams considered residual to petrochemical industries (butanes, pyrolisis gasoline, and heavy aromatics) can be applied to refiners to produce high quality transportation fuels, this can help the refining industry meet the environmental and quality regulations to derivatives.

The integration potential and the synergy among the processes rely on the refining scheme adopted by the refinery and the consumer market, process units as Fluid Catalytic Cracking (FCC) and Catalytic Reforming can be optimized to produce petrochemical intermediates to the detriment of streams that will be incorporated to fuels pool. In the case of FCC, installation of units dedicated to produce petrochemical intermediates, called petrochemical FCC, aims to reduce to the minimum the generation of streams to produce transportation fuels, however, the capital investment is high once the severity of the process requires the use of material with noblest metallurgical characteristics.

The IHS Markit Company proposed a classification of the petrochemical integration grades, as presented in Figure 7.

According to the classification proposed, the crude to chemicals refineries is considered the maximum level of petrochemical integration, where the processed crude oil is totally converted into petrochemical intermediates.

CLOSING THE SUSTAINABILITY CYCLE – PLASTICS RECYCLING TECHNOLOGIES

As described above, we are facing a continuous growing of petrochemicals demand and a great part of these crude oil derivatives have been applied to produce common use plastics. Despite the higher added value and significant economic advantages in comparison with transportation fuels, the main side effect of the growth of plastics consumption is the growth of plastic waste.

Despite the efforts related to the mechanic recycling of plastics, the increasing volumes of plastics waste demand most effective recycling routes to ensure the sustainability of the petrochemical industry through the regeneration of the raw material, in this sense, some technology developers have been dedicated investments and efforts to develop competitive and efficient chemical recycling technologies of plastics.

One of the most applied technologies for plastics recycling in the catalytic pyrolysis

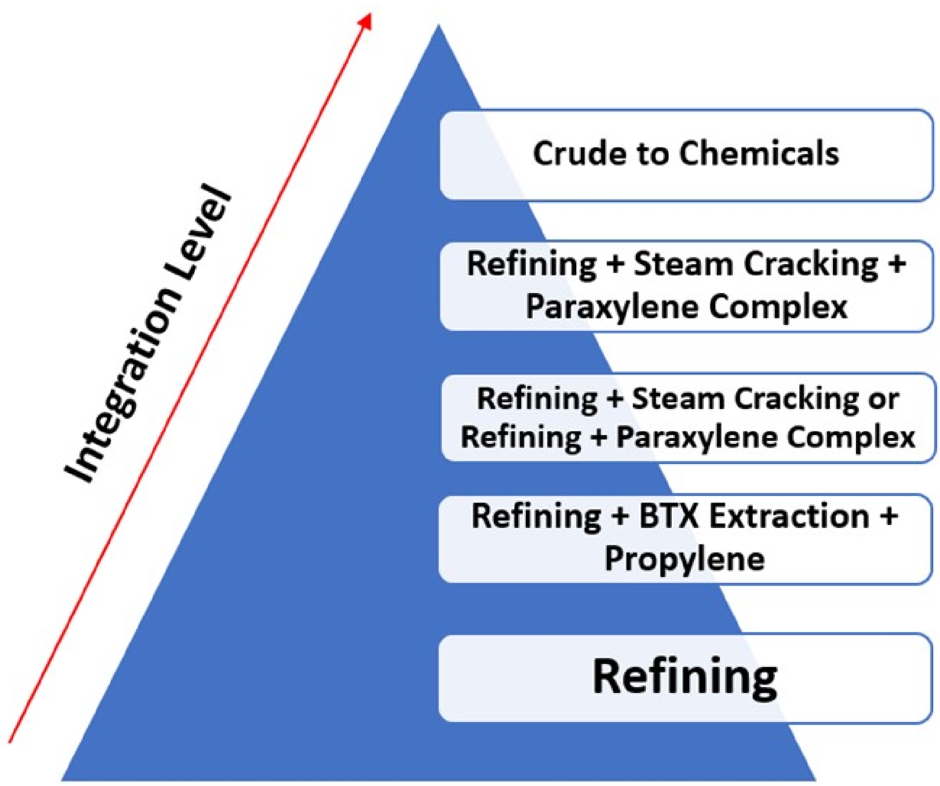

Figure 7 – Petrochemical Integration Levels (IHS Markit, 2018)

where the long chain polymeric are converted into smaller hydrocarbon molecules which can be fed to steam cracking units to reach a real circular petrochemical industry. Another route is the thermal pyrolysis of plastics, is this case, it's possible to quote the Rewind™ Mix technology developed by Axens Company.

Another promising chemical recycling route for plastics in the hydrocracking of plastics waste, in this case the chemical principle involves the cracking of carbon-carbon bonds of the polymer under high hydrogen pressure which lead to the production of stable low boiling point hydrocarbons. The hydrocracking route present some advantages in comparison with thermal or catalytic pyrolysis, once the amount of aromatics or unsaturated molecules is lower than the achieved in the pyrolysis processes, leading to a most stable feedstock to steam cracking or another downstream processes as well as is more selective, producing gasoline range hydrocarbons which can be easily applied in the highly integrated refining hardware. Figure 8 presents a summary of the available and promising routes to plastics recycling.

The chemical recycling of plastics is a great opportunity to technology developers and scientists, especially related to the development of effective catalysts to promote depolymerization reactions which can ensure the recovery of high added value molecules like BTX. More than that, the chemical recycling of plastics is an urgent necessity to close the sustainability cycle of an essential industry to our society, as presented in Figure 9, nowadays around 96 % of the plastic are not totally recycled and the UOP Company estimates that advanced recycling plastics technologies have potential to reduce this number to close of 17 %.

SOME COMMERCIAL PLASTICS RECYCLING TECHNOLOGIES

Due to the relevance of the topic, the main refining technologies developers are engaged to develop competitive technologies capable to recycle plastics in an efficient manner. Figure 10 presents an overview of the Rewind™ process developed by Axens Company.

Among another plastics recycling technologies we can quote the UpCycle™ process developed by UOP Company and the ChemCycling™ process in development by BASF Company which applies the pyrolysis route to produce pyrolysis oil which will be applied as feedstock to the production of petrochemical intermediates. The Hoop™ process, in development by Versalis Company, presented in Figure 11, is another plastics recycling process based on pyrolysis route.

Another commercial technology based on pyrolysis route is the New Hope™ process, developed by Lummus Company which can reach a yield of 70 % of liquid hydrocarbons for further processing according to the licensor.

It's fundamental to understand that the plastics recycling is necessary to the achievement of a real circular economy as required by the society, especially considering the growing demand for petrochemical intermediates in the next years. Data from 2019 pointed that there is around of 300 US billion dollars in capital investment to build crude to chemicals refining assets which are focused to produce petrochemicals from crude oil, with minimum transportation fuels which face a hostile environment. Close to 64 % of this capital investment are localized in the Asian Market, leading to a potential imbalance in the global downstream market.

These data reinforce the relevance of the plastics waste recycling technologies to the sustainability of the downstream industry at the same level of the energy management efforts of the players of this industry.

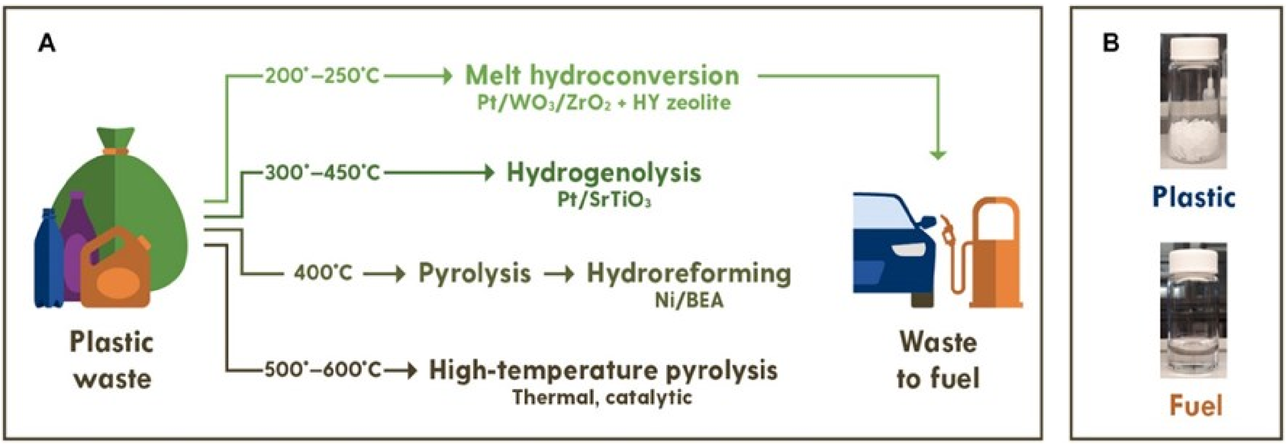

Figure 8 – Current and in Development Route of Plastics Waste Recycling Routes (LIU et. al., 2021)

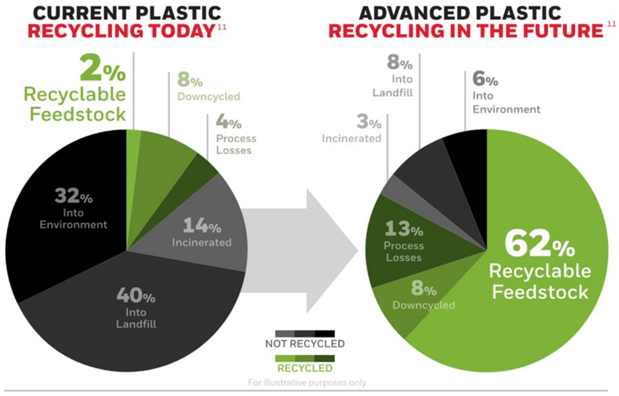

Figure 9 – Current and Future Plastics Recycling Scenario (UOP Company, 2021)

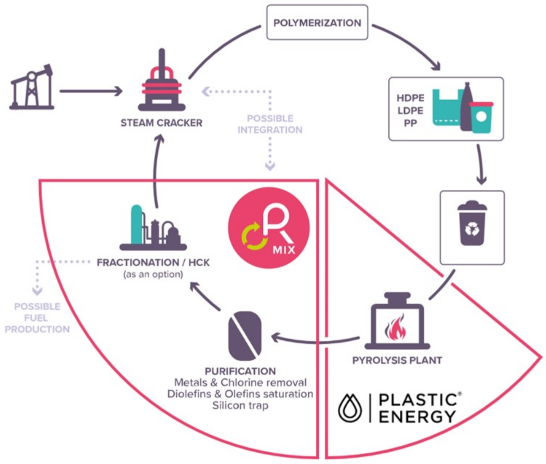

Figure 10 – Rewind™ Plastics Recycling Technology by Axens Company

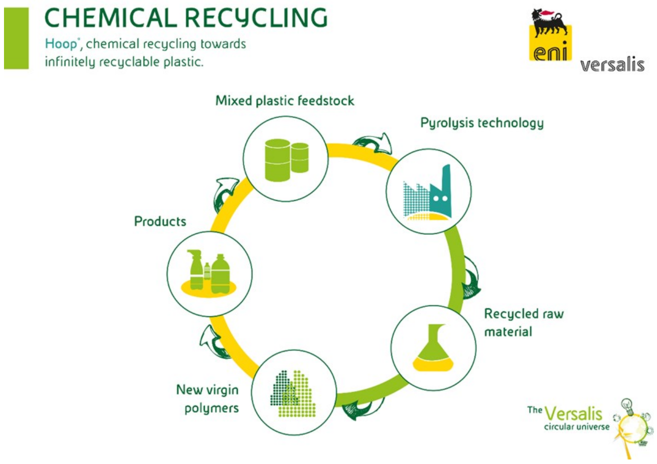

Figure 11 – Hoop™ Plastics Recycling Technology by Versalis Company

CONCLUSION

Nowadays, is still difficult to imagine the global energetic matrix free of fossil transportation fuels, especially for in developing economies. Despite this fact, recent forecasts, and growing demand by petrochemicals as well as the pressure to minimize the environmental impact produced by fossil fuels creates a positive scenario and acts as main driving force to closer integration between refining and petrochemical assets, in the extreme scenario the zero fuels refineries tend to grow in the middle term, especially in developed economies.

The synergy between refining and petrochemical processes raises the availability of raw material to petrochemical plants and makes the supply of energy to these processes more reliable at the same time ensures better refining margin to refiners due to the high added value of petrochemical intermediates when compared with transportation fuels. The development of crude to chemicals technologies reinforces the necessity of closer integration of refining and petrochemical assets by the brownfield refineries aiming to face the new market that tends to be focused on petrochemicals against transportation fuels, it's important to note the competitive advantage of the refiners from Middle East that have easy access to light crude oils which can be easily applied in crude to chemicals refineries.

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As presented above, the market forecasts indicates that the refiners able to maximize petrochemicals against transportation fuels can achieve highlighted economic performance in short term, in this sense, the crude oil to chemicals technologies can offer even more competitive advantage to the refiners with capacity of capital investment.

In the extreme side of the petrochemical integration trend, there are the zero fuels refineries, as quoted above, it's still difficult to imagine the downstream market without transportation fuels, but it seems a serious trend and the players of the downstream sector need to consider the focus change in his strategic plans like opportunity and threat. As discussed above, even the players with less capital power can take actions to maximize the petrochemicals yield in their refining hardware. Despite this scenario, disruption is still a hard word in the case of downstream industry, but the crude to chemicals refining assets can produce a competitive imbalance in the market, especially due to the concentration of capital investments in the Asian market. Less integrated refiners tend to compete in a kind of red ocean market where the refining margins tends to be lower due to the lower added value to the crude oil like transportation fuels, high sulfur fuel oil, and asphalt. Despite this, and according to the characteristics of the local markets it's possible to reach economic sustainability, in this case, the capital discipline and operational efficiency are even more important for these players.

Despite the benefits of petrochemical integration, it's fundamental taking in mind the necessity to reach a circular economy in the downstream industry, to achieve this goal, the chemical recycling of plastics is essential. As presented above, there are promising technologies which can ensure the closing of the sustainability cycle of the petrochemical industry.

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Cooling Tower Makeup Water Estimation

Jayanthi Vijay Sarathy

Cooling Towers in Process Industries are part of Utilities design. As the name suggests their primary purpose is to provide cooling requirements to industrial hot water from unit operations & unit processes. Examples include chillers and air conditioners. The principle of operation is to circulate hot water through a tower and allow heat dissipation to the ambient. Cooling towers can operate by natural draft or forced draft methods wherein fans are used to increase heat transfer. Below is a schematic of a cooling tower.

Cooling towers [CT] however experience drift, evaporation losses & blowdown losses.

Evaporation losses pertain to the water lost to the ambient due to evaporation.

Drift losses refer to water escaping as mist or tiny droplets and this can be reduced by using baffles or drift eliminators.

Blowdown losses refer to water with concentrated total dissolved solids [TDS] removed from the system to reduce scaling. As the water evaporates, the TDS concentration increases, aiding in the formation of scales due to calcium, silica, magnesium, chlorides, etc. As a result, water needs to be removed from the water basin at the bottom of the cooling tower.

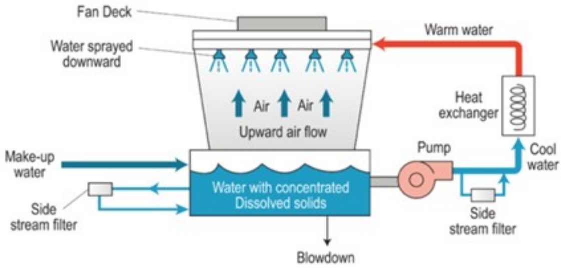

Figure 1. Cooling Tower Schematic [6]

Therefore the makeup water rate, M [m3/h] can be estimated as,

$$M = E + B + D \quad (1)$$

Where, E = Evaporation Losses [m3/h]

B = Blowdown Losses [m3/h]

D = Drift Losses [m3/h]

To quantify the makeup water efficiency of the cooling tower, a parameter called Concentration of Cycle [C], is introduced. Makeup water also contains TDS, because of which as the makeup water enters into the system, so does the TDS content increases relative to the TDS in the system water. Therefore if the concentration of cycle is 4, then the TDS in the CT system is 4 times the TDS in the makeup water supply. Higher cycles of concentration allows reducing the makeup water quantity for blowdown losses, however this also means increasing the risk of scale formation which can cause corrosion.

GENERAL NOTES

1.Cooling Tower Range [R] can be defined as the temperature difference between hot water entering and cold water exiting the system.

$$R = T_H - T_C \quad (2)$$

2. Approach [A] can be defined as the difference between temperature of cold water [TC] and ambient dew point temperature [TW].

$$A = T_C - T_W \quad (3)$$

3. The cooling tower effectiveness [% Efficiency] can be defined as,

$$\%\,Efficiency = \frac{R}{R+A} \times 100 \quad (4)$$

4. The evaporation losses as per Perry's Handbook can be evaluated using the empirical relationship,

$$E\ [m^3/h] = \frac{C_E}{100} \times \frac{R}{5.56} \times Q_C \quad (5)$$

Where,

C_E = Evaporation Loss Constant

Q_C = Circulation Rate [m3/h]

The above empirical expression is based on the assumption that the rate of evaporation is approximately 1% of the circulation flow for each 5.560C temperature rise of the Range. The value of CE can be taken as 0.85. For more humid climates the value of CE decreases while CE increases with drier atmosphere. Therefore for moist climates, the value of CE can be taken as 0.65 and 1.0 to 1.2 for very arid conditions [2].

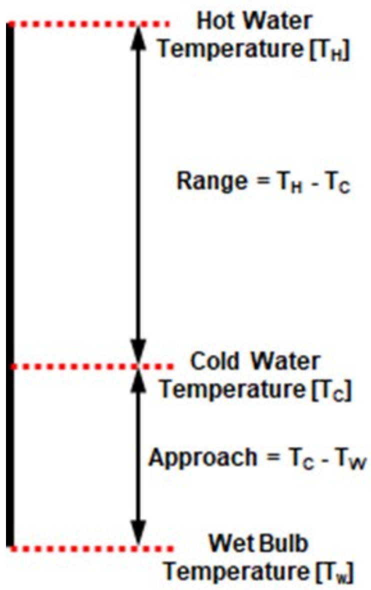

Figure 2. Cooling Tower Range & Approach

5. Alternatively based on a heat balance, the evaporation losses can be estimated by equating the heat removed from the water to the heat absorbed by the ambient air. Therefore the % evaporation becomes,

$$\%E = \frac{[Q_c \times \rho] \times C_p \times [T_H - T_C]}{\lambda_v \times [Q_c \times \rho]} \times 100 \quad (6)$$

Taking R = T_H-T_C

$$\%E = \frac{C_p \times R}{\lambda_v} \times 100 \quad (7)$$

The evaporation rate is estimated as,

$$E = \frac{\%E}{100} \times Q_C \quad (8)$$

Where,

C_p = Specific Heat of Water [kJ/kg.K]

l_v = Latent Heat of Vapourization [kJ/kg]

6. The drift losses [D] can be estimated as a percentage of the Total circulation rate, i.e.,

Natural draft CT, $D = 0.3\ to\ 1.0 \times Q_C$ (9)

Forced draft CT, $D = 0.1\ to\ 0.3 \times Q_C$ (10)

7. Blowdown Rate is a function of the cycle of concentration and is expressed as follows,

$$B[m^3/h] = \frac{E}{C-1} \quad (11)$$

The cycle of concentration[C] is typically kept between 3.0 and 7.0.

8. To improve cooling tower efficiencies, they can be retrofitted with provisions such as – Side Stream filtration system to filter out silt and suspended solids.

9. Water softening systems can also be installed since the cycles of concentration are limited by the amount of TDS.

10. Installing a cover on open distribution system to reduce sunlight & prevent biological growth.

11. Chemical Monitoring systems can be installed to monitor scale and corrosion Float Control can be added to prevent basin leaks and overflow.

EXAMPLE CASE

A forced draft cooling tower operates with a capacity 1,000 m3/h. The inlet water temperature is 400C which requires to be cooled to 300C. Taking a drift loss percentage of 0.2% and number of cycles of 4.0, calculate the makeup water requirement. The specific heat of water is taken as 4.179 kJ/kg.K and the latent heat of vapourization is 2,429 kJ/kg. To estimate using Perry's Method, the correction factor is taken as 0.85. The dew point temperature at 350C ambient and relative humidity of 50% is 230C.

Cooling Tower Range

The Cooling Tower Range [R] is,

$$R = 40 - 30 = 10°C \quad (12)$$

Cooling Tower Approach

The Cooling Tower Approach [A] is,

$$R = 30 - 23 = 7°C \quad (13)$$

Cooling Tower Efficiency

The Cooling Tower Efficiency [%E] is,

$$\%\ Efficiency = \frac{10}{10+7} \times 100 = 58.8\% \quad (14)$$

Cooling Tower Evaporation Losses

The Cooling Tower Evaporation Losses is,

$$\%\ E = \frac{4.179 \times 10}{2{,}429} \times 100 = 1.72\ \% \quad (15)$$

$$E = \frac{1.72 \times 1{,}000}{100} = 17.2\ m^3/h \quad (16)$$

Using Perry's Method, the evaporation loss is,

$$E = \frac{0.85}{100} \times \frac{10}{5.56} \times 1{,}000 = 15.3\ m^3/h \quad (17)$$

Cooling Tower Drift Losses

The Cooling Tower Drift Losses is,

$$D = \frac{0.2}{100} \times 1{,}000 = 2\, m^3/h \quad (18)$$

Cooling Tower Blowdown Losses

The Cooling Tower Blowdown Losses is,

$$D = \frac{17.2}{4-1} = 5.73\, m^3/h \quad (19)$$

Using Perry's Method, the Blowdown Loss is,

$$D = \frac{15.3}{4-1} = 5.10\, m^3/h \quad (20)$$

Total Makeup Water Requirements

The Total Makeup Water Requirement is,

$$M = 17.2 + 5.73 + 2 = 24.9\ m^3/h \quad (21)$$

Using Perry's Method, total makeup water is,

$$M = 15.3 + 5.10 + 2 = 22.4\ m^3/h \quad (22)$$

APPENDIX: CALCULATIONS

Cooling Tower Make up Water Calculations		
Total Circulation Rate [Q_C]	**1,000**	m^3/h
Hot Water Temperature [T_H]	**40.0**	°C
Cold Water Temperature [T_C]	**30.0**	°C
Ambient Air Dew Point	**23.0**	°C
Cycles of Concentration [C]	**4.0**	-
Range [R]	10.0	°C
Approach [A]	7.0	°C
% Efficiency	**58.8**	%
Evaporation Losses [E]		
Specific Heat of Water [C_p]	4.179	kJ/kg.K
Latent Heat of Vapourization [λ_v]	2,429	kJ/kg
% Evaporation	1.72	%
Evaporation Losses [E]	**17.2**	m^3/h
Correction Factor [Perry's Method]	**0.85**	-
Evaporation Losses [E] [Perry's]	**15.3**	m^3/h
Drift Losses [D]		
Drift Loss %	**0.20**	%
Drift Losses [D]	**2**	m^3/h
Blowdown Losses [D]		
Blowdown Losses [D]	**5.73**	m^3/h
Blowdown Losses [D] [Perry's Method]	**5.10**	m^3/h
Make Up Water Requirements [M]		
Make Up Water Requirements [M]	**24.9**	m^3/h
Make Up Water Requirements [M] [Perry's]	**22.4**	m^3/h

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ASME - S AND U Stamp

Avoiding the "Sunk Cost Swamp" is Key to New Energy Project Success

Anne B. Keller

During these uncertain times, the survival of a business will depend on its ability to plan and execute projects within tighter financial constraints than many current project managers have likely ever experienced. But when the new projects are based on technology that hasn't been scaled, or at least not successfully, will lessons from projects in the recent past enough to launch a successful moonshot?

Trust Monty Python to say it best. In a scene from "Monty Python and the Holy Grail" that brings rueful smiles to the faces of many who have been involved in major projects over the years, the new CEO of the castle recounts the experience of the last person who was in the job:

"Listen, I built this (business unit) from nothing. When I started here, it was all swamp. Other (CEOs) said I was daft to build a castle on a swamp, but I built it all the same, just to show 'em. It sank into the swamp. So, I built a second one. That sank into the swamp. So, I built a third one. That burned down, fell over, then sank into the swamp, but the fourth one... stayed up! And that's what you're gonna get: the strongest castle in these islands."

The reason the new CEO has the job of course, is that the former CEO "left" after the third try. We are in a world where a massive amount of infrastructure development will be needed to shift the way energy and materials are created and delivered. The stakes for businesses that want to remain profitable and those who want to become the new businesses of the future are very high. There are some lessons to be learned from other industries that can help infrastructure experts build a castle that stands up the first time.

COST OVERRUNS | THE HIGH PRICE OF TECHNICAL SUCCESS.

Overspend on capital projects at the very minimum increases the financial risk involved in bringing a large amount of production capacity into the market, and can end up resulting in a rate of return that doesn't match stakeholder requirements. The issue of cost overruns is not new, and countless articles, conferences, and consulting projects have been devoted to addressing it. Recently the results of an internal study of capital project spending by Exxon, one of the largest "hard asset" companies in the world, were reportedly "leaked" to the press. The study covered project spend for a 20- year period from 1998 to 2017, when the energy and chemicals industry was spending billions on finding and developing new oil reserves in shale formations and increasing ethylene production capacity by over 61% in the US alone. Exxon wasn't alone in experiencing significant cost overruns –projects like Chevron's Gorgon LNG project in Australia, and Shell's Oryx Gas to Liquids project in Qatar are considered great technical successes, but their final costs are not publicly available.

WHAT DID EXXON LEARN?

According to Bloomberg, "the 2020 analysis found that "multiple runaway projects" were the result of insufficient design and planning work. "Some projects locked into specific concepts too early, without fully considering other, better, options," the analysis said. "In the case of "runaway" projects that exceeded their early cost estimates by more than 70%, it was suggested that the planners may have been overly optimistic, possibly to move the project through the approval process in the early stages.

In other words, the project teams got lost in the Sunk Cost Swamp, since the work proceeded in spite of growing cost overruns. The article notes that "Exxon has "reduced complexity and internal interfaces, allowing faster decision-making and significant efficiencies," (CEO) Darren Woods told investors in March. The improvements, he said, preserve "the functional excellence we've built over decades."

DRAINING THE SUNK COST SWAMP | IDENTIFY THE KEY ISSUES AT THE BEGINNING

There are a couple of lessons in the Monty Python sketch that we could learn from when we stop laughing that Exxon's report doesn't mention. The first is to figure out the biggest challenge to be resolved to make the project a success. A surprising amount of time this doesn't have much to do with the actual technology. For example, in the castle building exercise, the real challenge was figuring out how to create a stable platform to set the foundation on. A real life example of this was Cheniere's Sabine Pass LNG terminal. It was obvious the location was in a swamp. he project team spent the extra time and money during the early stages of the project to determine exactly how deep the swamp really was, and put in test pilings to make sure they could hold the superstructure. The net result was an additional $50 to $60 million in project costs, and a facility that is still standing 14 years later.

One of the consistent issues we hear from engineering and IT disciplines is the frustration with the reluctance of developers and project managers to budget enough money at the beginning of the project to gain real insight into the true success metrics and the critical path requirements needed to complete the project effectively and efficiently. The "pre-feasibility" and/or initial investigation phases are usually paid from money that's part of an overhead budget, and there is sometimes a sense that any findings that diverge from the high level assumptions being made by the project sponsors already working on the project will derail the effort. The net result is the project often proceeds with way more money committed to FEL 1 work, but since this part of the project is under a different budget, and sometimes funded by outside sponsors or economic development subsidies, the spend will be viewed as somehow acceptable.

The other issue involves staging of investments and is critical for the types of projects we're looking to build as part of the energy transition. A number of the ideas that are being pursued are true "moonshots" – they involve technology that hasn't been used widely outside smaller pilot facilities, and/or complexity and a level of scale that we've never seen before. In this case, where both the stakes and uncertainty level around the commercial acceptance of the project are high, another type of pre-feasibility analysis is called for.

MOONSHOTS AND "MONKEY TRAINERS" IMPROVING THE DO-ABILITY SCORE FOR NEW TECH

In our work with clients developing business strategy, we create scorecards designed to describe, quantify, and rank the options generated by the study group. Since the primary end goal for a business is usually to generate rate of return on investment that meets or beats a set target, most of the factors we use are quantitative, such as expected margin, up front capital, and costs. But we also include another qualitative factor we call "Do-ability". This factor includes an assessment of the resources at hand available to execute – including corporate culture, staffing, and level of commitment to a particular type of strategy. A strategy that involves buying 2 competitors could be feasible given enough budget, but in a company that has grown via incremental expansion of its existing asset base the need for a change in attitude and additional skills needs to be considered before moving forward. Doing this before project teams begin work on development can avoid unnecessary spending.

A version of the "do-ability" assessment that's easier to remember is the approach used by the team at Google X, Alphabet's own "moonshot lab". Although Google is much better known for selling ads than building industrial plants, the team is working on projects that involve real world assets. Their process is nicknamed #MonkeyFirst, and it's used to find out quickly whether a project is worth pursuing before spending time and money on detailed feasibility. The name comes from the idea that creating world changing technology involves a challenge that's similar to getting a monkey to stand on a pedestal reciting Shakespeare. If that's the challenge, where would they begin?

"The right answer, according to business unit lead Astro Teller, is training the monkey. The wrong answer is building the pedestal. That's because training the monkey is infinitely harder than building the pedestal -- and at X, it's imperative to do the hardest thing first. "You can always build the pedestal. All of the risk and the learning comes from the extremely hard work of first training the monkey." An example of how this works in practice was a project designed to turn sea water into carbon neutral fuel. The focus, as in many of the new energy projects we see today, was on the technology. The "monkey" in this case was being able to make it at a competitive cost. The technology was basically the pedestal – the team could report progress in getting it working, but not in getting it sold.

The technology was basically the pedestal – the team could report progress in getting it working, but not in getting it sold.

There are a number of projects and businesses today that have successfully built technological pedestals, but are finding out, some after raising and spending billions, that the monkey is harder to train than they'd thought. A couple of examples are Tesla and the Hyperloop project. Tesla is considered extremely successful in making electric vehicles. They have yet to demonstrate how to make the batteries at a competitive cost, without consuming vast quantities of energy and using slave labor, and without raising the price of the raw materials beyond where they are today. The electric vehicle industry has yet to address how drivers will pay for their part of the

The solutions that are offered seem to be a version of spending whatever it takes to make it possible to put more EV's on the road, but the limits of society's ability to pay for them are rapidly being reached. The Hyperloop project involved the idea of sending humans through a tube at rapid speeds in a vacuum system like money was transferred from a drive-up teller at a bank. The Google X team opted to pass on further spending when they determined they would have to essentially build out the whole system in order to test it properly with real humans

Applying this to many hydrogen projects indicates that the actual 'monkey' to be trained isn't the technology for creating hydrogen. It's how to put it into a form that allows it to be transported for use in other locations. Hydrogen isn't compatible with most existing pipelines that transport oil and natural gas currently at high concentrations. How much money will be spent before this becomes an obvious issue?

For companies whose goal is to "place" capital in a world where money is abundant, it may be enough to build pedestals. But for companies whose goal is to generate a sustainable return on investment for their stakeholders, and truly change the world, it's time to look for monkey trainers who can walk in swampy water.

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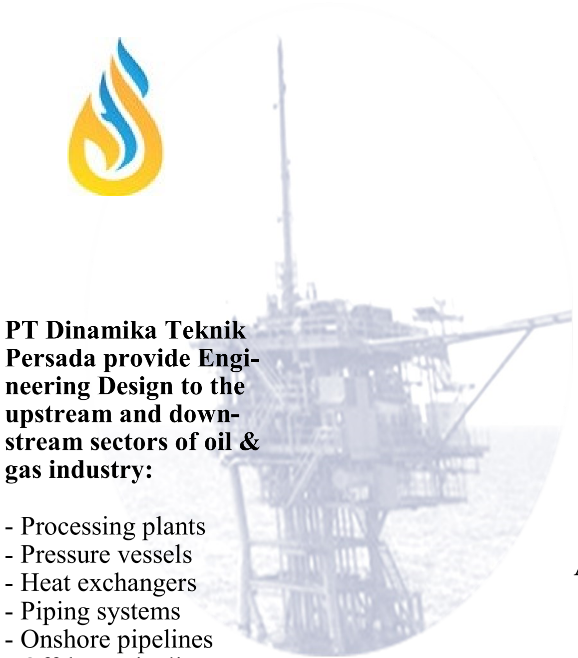

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offers an interactive 3D-view for all designs
can be used for single stage, profile and data validation calculations
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2022 Nov Dec update for the South East Asia (SEA) O&G industry

November 2022

KEY DRIVING FACTORS

Carbon tax in Singapore is driving O&G players to look into mitigation and alternatives. Other countries also make progress in their assessments. At SG$5/MT C tax margin impact is estimated at US$0.2/barrel or approx. US$120M/yr. for Singapore refining capacity.

Refining and petchem spread getting thinner. Petchem loads getting trimmed back as margins thin. Seeing this across SEA.

Manpower movement across industry makes hiring and keeping talents a more pressing problem.

HIGHLIGHTS

Q3 financial results showing record profits seen by all most O&G players including Exxon, Shell, Petronas, Pertamina amongst others due to souring energy prices.

Shell advances carbon capture and hub for Singapore and Brunei by collaboration between Shell Eastern and BSP.

Sembcorp links up with Japanese companies in Singapore to use a liquid organic hydrogen carrier while other options are being looled at by the industry like ammonia.

Petronas reviewing green hydrogen from biomass.

RECENT EVENTS

Singapore International Energy Week was held on 25-28th October 2022.

ASIA ESG & Sustainability Summit was held on 13-14 October 2022.


Engineering Design Software
Specialized technical articles and books
Detailed Engineering Design Guidelines
Project Engineering Standards and Specifications
Typical Process Unit Operating Manuals
Training Videos

Rock Bottom View: "Sustainability/Renewability…. What the Heck is it Really All About"

Ronald J. Cormier, *Engineering Practice* Contributing Author

Howdy again. EPM's November edition offers another chance to chat and compare notes on critical issues driving the future of our industry. Before, I have come to you from my old writing desk on the deck of my Rock Bottom Ranch house in Texas. During September, the theme was **"Man, it's really hot outside!".** To that end, I am making a soft transition toward relocation down to Mexico and so, have put the Texas ranch on the sale block. The central Texas spread is indeed a sweet place, but the reality of global warming has become personal; the summers are just too brutally hot.

After lots of research and travel to determine the "world's best climate", I believe the mountains of western Jalisco, Mexico, to the east of Puerto Vallarta provides that answer. At 5000 feet of elevation, the climate is temperate, usually in the 70'sF/21C and varies only about twenty degrees F/7C during the year. Summer is rainy and provides for bountiful soil and produce. Winter is dry and rarely freezes. Amenities are plentiful nearby in Puerto Vallarta. My hope is to maintain this sweet balance as long as possible.

Continuing our monitoring of, and responsible leadership toward, improved global climate/ water/soil plus simultaneous plentiful energy/ durable goods, we would appreciate your thoughts.

SUSTAINABILITY IN ENERGY AND PETROCHEM: WHAT TO EXPECT SOON

The words "sustainable" and "renewable" are often used to describe certain sources of primary energy, often interchangeably. However, these words have very different meanings. Not everything renewable is sustainable, and in turn, not everything which is sustainable is necessarily renewable.

RENEWABLE ENERGY

Literally 'to make new again', a renewable resource is one that is naturally replenished with time, like the growth of new organisms or natural recycling of materials. Renewable energy is any energy production which uses one of these resources. Renewable resources do not have a fixed quantity - more can always be generated. However, if the rate of use exceeds the rate of renewal - that is, the source is used more than it's being recreated - its continued use will become unsustainable.

Generally, renewable energy is taken to mean any of the following:

Solar power

Wind power

Hydropower

Tidal power

Geothermal power

Resources are considered non-renewable if they take a very long time to be created (e.g., fossil fuels) or if their creation happened long ago and is not likely to happen again (e.g. uranium). Primary energy flows are almost always renewable. On the other hand, biofuels are renewable and definitely count as fuels.

SUSTAINABLE ENERGY

Literally, that which can be maintained for a finite period of time, sustainable energy is energy production that can last for the foreseeable future. Sustainable energy practices must rely on resources which can continue to supply our needs. These sources must be used cautiously so that they will not be used up, run out, or otherwise become unusable.

Even renewable resources can become unsustainable. If a resource is used up faster than it can regenerate, it will eventually be entirely depleted despite its renewability. Conversely, a non-renewable resource can be sustainable if it's used in moderation. Again, if used without caution, these too may become be depleted in a short time.

For most people, sustainable energy use means that the environment is not significantly damaged due to accumulated effects of an energy practice. This part of the definition of sustainable energy is quite politically charged with widely varying opinions. Often advocates for fossil fuels will claim that coal, oil and natural gas are sustainable because the reserves for these are so large, discounting their combustion emission and problems with climate change. To operate, the fuels/petrochemical sector needs 30% of the Earth’s carrying capacity and the industry contributes significantly to carbon emissions. Chemicals made from naphtha and other fossil fuels, like ethylene and propylene, demand a lot of resources that are not currently sustainable enough commercially.

The trajectory is shifting, though, in favor of more environmentally friendly, renewable, and bio-based goods. There are many opportunities that are even profitable, thanks to the use of renewable energy in the oil/petchem sector. The future of the oil/chemical industry will be dominated by sustainability and technological advancements in the coming years, for sure.

The primary concern for the industry is not just carbon emissions, but also the intensity of these emissions. All of the carbon dioxide released to produce electricity, accounts for this emission intensity. When fossil fuels are used, the intensity of carbon emissions increases, and this is where sustainable efforts can alter the narrative.

THE 2 DEGREE CELSIUS SCENARIO

After nations endorsed the 2015 Paris Agreement, the sustainability issue as a whole was well-received. That agreement included a number of requests for modifications, adaptations, and innovations. The commitment to keeping the average global temperature rise below 2 degrees Celsius, and lowering it all the way to 1.5 degrees Celsius is what sparked the wildfire.

To accomplish the stated goal, the oil/petrochemical industry needs strong commitment, but it was challenging to dig deep enough for large-scale businesses. There is still no assurance that the goals set forth will be accomplished because a significant reduction in energy consumption is required. But gradually, to some extent, the operations have changed, moving the agenda forward in baby steps.

So how can it be achieved?

Any oil/petchem company attempting to join the 2 degree Celsius propaganda would not be able to increase its production capacity using conventional methods. Depending on the situation, using sustainable and renewable energy sources may be the only viable option. Switching from the use of fossil fuels for production to renewable sources can help create a circular economy. In order to make this transition without losing market share, strategic business planning and portfolio management are required.

CLEAN TECH MOVEMENT

Technology that is renewable and clean does not always imply the use of solar or wind power. Clean technology emphasizes the ability to use energy more effectively while producing products that are readily able to be recycled, reused, or reproposed. Additionally, this entails switching the raw material to something renewable, an extract, or a byproduct from another industry.

The topic of conversation right now is operational improvement.

Many petrochemical startup companies are developing innovative SaaS (subscription software) products with cutting-edge technology with the help of IoT (internet of things) in this regard, Digital Oilfields is an intriguing development to be aware of, where technology enables customized surveillance, providing useful information for enhancing overall operations.

Funding sharks are working with startup companies and accepting technological and innovative aspects in order to fulfill their commitment to building a sustainable industry. However, switching from outdated models to new ones will take some time.

For the oil/petchem industry sustainability makes a key priority, as they need to embrace new principles and processes to fight one of humanity's main challenges. United Nations have adopted 17 Sustainable Development Goals (SDGs), and two of them greatly impacting oil and gas industries: "Affordable and clean energy" and "Climate action".

Due to great volume of responsibilities to regulatory bodies, the financial community, the investors, their clients and the civil society, many companies from oil/petchem industry started implementing these goals into their operational processes. Worldwide, companies are responsibly moving the world forward to a net zero carbon future. Organizations across industries are under increasing pressure from stakeholders, regulators, and customers to report and manage the environmental impact of their business. **Technology has an important role to play in executing sustainability strategy and helping the industry decarbonize.**

FOUR STEPS TO SUSTAINABLE FUTURE PER ACCENTURE AND MICROSOFT…

For starters, the companies need to establish a true baseline — understanding holistically the environmental footprint of the organization and value chain across all scopes: emissions that directly result from its business activities; emissions from producing energy such as electricity or heating and cooling; and indirect value chain emissions as a result of other business activities, such as building and construction materials or transport.

As a first step for building successful sustainability strategy, companies need better visibility to effectively drive sustainability reporting, sustainability efforts, and business transformation. For example, collecting and connecting IoT data from devices using sensors—combined with rich services at the edge or in the cloud—provides the basis to monitor and measure activities at scale.

Secondly, the companies should identify opportunities to replace tools, systems, or activities with more efficient options and add business value. A key place to begin is evaluating the company's compute resource utilization, storage, and networking efficiencies. Simply migrating from on-premises cloud services to a hyperscale or to hybrid cloud have been shown to yield carbon and energy efficiency improvements.

Third step for sustainability strategy is to minimize the environmental footprint of company's operational systems and processes. Integrated data solutions enable organizations to examine and manage the footprints of their facilities and production processes and shift the activities of their people to be responsive to the changing requirements of a sustainable economy. For example, the use of advanced technologies can enable autonomous operations that continuously maximize efficiencies of your building systems or manufacturing processes.

The fourth step is to facilitate greater transparency and accountability through value chain, from raw materials to product creation to distribution. Up to 90 percent of an average organization's resource footprint occurs in the value chain—either upstream (through the supply chain) or downstream (in the product use phase) of its own operations. Without data, the companies can't know the full impact of each supplier in their supply chain or understand the cost and climate impacts of changing suppliers.

GOVERNMENT INTERVENTION AND SUPPORT FOR SUSTAINABILITY

Various governments have been actively promoting sustainability; for instance, Japan and South Korea have made commitments to achieve net-zero emissions by 2050. China, on the other hand, has outdone other nations by pledging to have net-zero emissions by 2030 and has set a goal of becoming carbon neutral by 2050. Similar to this, the Indonesian government has mentioned working with companies to reduce 29% of carbon emissions by 2030.

It is safe to say that European and Asian nations are working hard to clean up and green up their petrochemical industries. This unquestionably encourages players and industries to develop ever-more sustainable business models, which helps the world succeed as a whole.

CHANGING MARKET SYNERGY

With its sustainable ecosystem, lower costs, and enhanced functionality, the clean tech movement is here to stay. Investors are being picky when funding projects in the wake of the Paris Agreement, looking at how sustainable the operations in question are. Poor sustainability controls, procedures, and operations are a growing concern, but businesses are adjusting to the change gradually but steadily. The market is flooded with new ideas and technological advancements. New ideologies to reduce carbon footprints are being introduced by important players and start-ups, and largely will occupy STEM careers for current and coming technical graduates.

Recently, BASF announced plans to increase the production of synthetic ester base stocks by twofold. This is directly related to the product's numerous long-term advantages. These include, but are not limited to, cost savings, emissions reduction, biodegradability, and so on.

SABIC, a global leader in chemicals, offers another illustration. In a new collaboration with Kraton, SABIC introduced "certified renewable butadiene." When compared to butadiene made from fossil fuels, it is asserted that each kilogram of this renewable butadiene can cut carbon emissions by up to 4 kg. The second generation renewable feedstock used to create SABIC's renewable butadiene is free of palm oil and animal products, making it a great example of green technology.

Another crucial aspect of sustainability and the circular economy is recycling. With the recycling of flexible polyurethane foam from old mattresses, Covestro has been doing some amazing work there. Unilever, Danone, and Coca-Cola, among others, have made commitments to use less plastic in their consumer packaged goods.

Some energy companies have already started to pivot a huge part of their investment to production of renewables and have depreciated or divested some of their oil assets. Large corporations such as Shell, bp, Kazakhstan, have launched ambitious action plans. With the right technology in place, innovative approaches companies can pivot rapidly to meet changing market demands and circumstances and achieve their sustainability goals. and Chevron, some also operating in Key players are looking at a range of collaborations with businesses that provide recyclable and sustainable solutions. This has two benefits: it improves brand recognition and encourages market funding and support. The market has seen a lot of activity, and the interest in sustainability is only going to increase. Energy efficiency, low carbon dioxide emission processes, and lighter feedstocks could all be advantageous to the concept as a whole.

IN A NUTSHELL

The oil/petrochemical sector faces ongoing environmental challenges, so reforms are necessary. An IEA report claims that Clean Technology Scenario products can contribute to the development of a sustainable society, and by 2050, air pollutants from fuels/chemical production should have decreased by 90%. It would be interesting to see how the players contribute to the overarching oil/fuels/ petrochemical sustainability ideology in light of such lofty claims.

A number of factors, such as supply chain disruptions and political-social problems, have had an impact; the industry may experience significant value chain shifts, contributing to a sustainable planet. There may be a delay, but the certainty of change is visible in the eroding of barriers, the original ideas, and the passion for a cleaner world in general. As always, we will keep an interpretive eye on related developments down the road and bring them to you, our valuable readers. Until January, please enjoy safe and joyous holidays.

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GHS REQUIREMENTS ARE CONFUSING
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Benchmarking Waste Water Treatment Systems

Karl Kolmetz, Cheah Phaik Sim

ABSTRACT

Engineers today have a dual responsibility. There is the responsibility to produce the chemicals needed for food, medicine, and improvements in life style. Coupled with this need for chemical production is the need to produce these requirements with fewer impacts to the environment.

There are two routes to reduce the impacts to the environment. The first route is to develop processes that produce fewer unwanted by-products, the minimization of waste generation. The second route is the transformation of the unwanted by-products to streams of low environmental impact.

Each chemical plant constructed should include each of the routes. The transformation of the unwanted by-products to streams of low environmental impact is called the Waste Water Treatment System. It can process streams of various compositions and transform them to the desired streams of low environmental impact.

The Waste Water Treatment System has a variety of unit operations. They include gravity separators, mechanical separators, filters, stripper towers, aeration and clarifiers basins, as well as others. The transformation of the by-product streams is based of the effectiveness of each of these unit operations.

Each of these unit operations has three values.

- Industry Standard Design Value
- Actual Design Value and
- Present Operating Value

The difference between the values can be benchmarked to establish areas good operation and areas of opportunities for improvements.

An overview of each of the unit operations of a Waste Water Treatment System will be constructed and industry guidelines will be given for individual unit benchmarking.

INTRODUCTION

Many industries use large volumes of water in their manufacturing operations. Industrial Waste Water Treatment Systems treat wastewater from an industrial or manufacturing process such as a cooling tower, food or animal processing plant or any type of manufacturing process that generates wastewater. The Pulp and Paper, Steel, Refining, and Chemical industries account for more than 90% of the water used by industries in North America.

The treatment process and equipment is specifically directed to control or remove certain organic or chemical compounds. The flow may or may not contain domestic wastewater and ranges from several hundred to several million GPD. Industrial applications can present challenges that are specific to the plant or process. Maintenance on these systems is always mandatory and contains specific performance parameters.

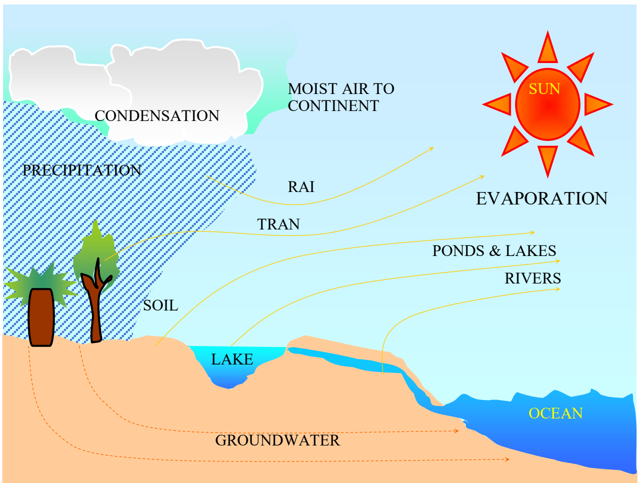


Figure 1- The Water Cycle

Atmospheric oxygen can replenish the dissolved oxygen consumption to exceed this re-supply; the dissolved oxygen level drops, leading to the death of fish and other aquatic life.

Under extreme conditions, when the dissolved oxygen concentration reaches zero, the water may turn black and produce odors. Organic compounds are normally measured as chemical oxygen demand (COD) and biochemical oxygen demand (BOD).

The amount of organic material that can be discharged safely is defined by the effect of the material on the dissolved oxygen level in the water. Organisms in the water use the organic matter as a food source. In a biochemical reaction, dissolved oxygen is consumed, as the end product of water and carbon dioxide are formed.

Atmospheric oxygen can replenish the dissolved oxygen consumption to exceed this re-supply; the dissolved oxygen level drops, leading to the death of fish and other aquatic life.

Under extreme conditions, when the dissolved oxygen concentration reaches zero, the water may turn black and produce odors. Organic compounds are normally measured as chemical oxygen demand (COD) and biochemical oxygen demand (BOD).

Industrial Waste Water Considerations include;

1. Volume of daily flow
2. All biological and chemical characteristics of the wastewater,
3. Including biodegradability, toxic material content and any material covered by specific environmental regulations
4. Regulations of the local health department and federal or state Environmental Protection Agency

The Waste Water Treatment System can be broken down into distinct components. (2)

1. Pretreatment Units
2. Primary Treatment
3. Secondary Treatment
4. Tertiary Treatment
5. Sludge Handing (thickening and denaturing)
6. Sludge Disposal

WASTE WATER TREATMENT SYSTEM OVERVIEW

PRETREATMENT UNITS

SEDIMENTATION - GRAVITY SEPARATION

Sedimentation is the separation from water of suspended particles that are heavier than water by gravitational settling. The purpose of sedimentation is 1) clarification - to produce clean water, which can be used, recycled or further treated and 2) consolidation - to produce concentrated solids that can be more easily handled and treated.

Most waste treatment system employ a gravity separation step for suspended particle or oil removal. The settling rate of a particle is defined in terms of “free” verses “hindered” settling. A free settling particle’s motion is not affected by that of other particles, the vessel’s wall, or turbulent currents. A particle has a hindered settling rate if there is any interference from these effects. (2)

Gravity settling is employed primarily for removal of inorganic suspended solids, such as grit and sand. The equipment employed for gravity separation for waste treatment is normally either a rectangular basin with moving bottom scrapers for solids removal or a circular tank with a rotating bottom scraper.

Rectangular tanks are normally sized to decrease horizontal fluid velocity to approximately 1 foot per minute. Their lengths are three to five time their width and their depths are three to eight feet.

Circular clarifiers are ordinarily sized according to the surface area, because velocity must be reduced below the design particle’s terminal velocity. The typical design provides a rise rate of 600-800 gpd/ft^2.

API SEPARATOR

When wastewater contains appreciable amount of hydrocarbons, removal of these contaminants become a problem. Oil is commonly lower in density than water; therefore, if it is not emulsified, it can be floated in a separate removal stage or in a dual-purpose vessel that allows sedimentation of solids. For example, the refining industry uses a rectangular clarifier with a surface skimmer for oil and a bottom rake for solids as standard equipment. Stokes’ Law expresses the basic principle governing the separation of oil from water by gravity differential as follows:

$$\upsilon_p = \frac{g\left(\rho_p - \rho_w\right)d^2{}_p}{18\mu} \qquad (4)$$

Where:

up = particle settling velocity

g = acceleration due to gravity, 9.81 m/

ρp = density of particle

ρw = density of water

dp = diameter of particle

m = dynamic viscosity

PRIMARY TREATMENT – FLOTATION

AIR FLOTATION

Where the density differential is not sufficient to separate oil and oil-wetted solids, air flotation may be used to enhance oil removal. In this method, air bubbles are attached to the contaminant particles and thus the apparent density difference between the particles is increased.

Dissolved air flotation (DAF) is a method of introducing air to a side stream or recycle stream at elevated pressures in order to create a super saturated stream. When this stream is introduced into the waste stream, the pressure is reduced to atmospheric, and the air is release as small bubbles. These bubbles attach to contaminants in the waste, decreasing their effective density and aiding in their separation.

The most important operation parameters for contaminate removal by dissolved air flotation are; [1]

- Air pressure
- Recycle or slip stream flow rate
- Influent total suspended solids (TSS) including oil and grease
- Bubble size
- Dispersion

As in gravity settling, air flotation units are designed for a surface-loading rate that is a function of the waste flow and rise velocity of the contaminants floated by air bubbles. The retention time is a function of the tank depth.

DAF units can be rectangular in design by are usually circular, resembling a primary clarifier or thickener. They are often single stage units.

Induced Air Flotation (IAF) is another method of decreasing particle density by attaching air bubbles to the particles, however the method of generating the air bubble differs. A mechanical action is employed to create the air bubbles and their contact with the waste contaminants. The most common methods use high-speed agitators or recycle a slipstream through venturi nozzles to entrain air into the wastewater.

In contrast to DAF units, IAF units are usually rectangular and incorporate four or more air flotation stages in series. The retention time per stage is significantly less that in DAF circular tanks.

As in gravity settling, the diameter of the particle plays an important role in separation. Polyelectrolytes may be used to increase effective particle diameters. Polymers are also used to destabilize oil / water emulsions, there by allowing the free oil to be separated from the water. Polymers do this by charge neutralization, which destabilizes an oil globule surface and allows it to contact other oil globules and air bubbles. Emulsion breakers, surfactants, or surface-active agents are also used in air flotation to destabilize emulsions and increase the effectiveness of the air bubbles.

FILTRATION

Filtration is employed in waste treatment whenever suspended solids must be removed. In practice, filtration is most often used to polish wastewater following treatment. In primary waste treatment, filters are often employed to remove oil and suspended solids prior to biological treatment. More commonly, filters are used following biological treatment prior to final discharge or reuse.

Filtration is also widely used as a tertiary treatment for suspended solids removal. The fundamental requirement is that the suspended particles are of sufficient size or capable of being increased in size by flocculation. In cases when it is not possible to flocculate such particles, more advanced techniques such as ultra-filtration is more practical.

Some of the advantages of filtration are as follows: [3]

1. Simple to operate and easy to control
2. Can be used for almost any type of free-flowing liquid stream containing suspended solid particles
3. Relatively cost competitive with regard to sludge dewatering processes
4. Lower energy consumption as compared to others
5. Can be integrated easily with other treatment trains

6. Great potential for recovery as the process will not chemically change the characteristics of the materials treated.

Some of the disadvantages, among others are: (3)

1. Not capable of producing a high purity effluent as both the liquid product and dewatered sludge still contain a certain fraction of the liquid and solid phase
2. Not capable of separating chemical components especially when they are present in the same phase.
3. Not capable of destroying or chemically changing the toxicity of materials
4. Will produce a liquid waste stream that requires further treatment prior to disposal.

ULTRA-FILTRATION

Ultra-filtration, by definition, is a membrane filtration process that separates high molecular weight solutes or colloids from a solution or suspension. The process has successfully been applied to both homogeneous solutions and colloidal suspensions that are difficult to separate practically by other techniques.

The types of membrane used for ultra-filtration are similar to reverse osmosis membranes that are made of cellulose acetate and nylon. It has demonstrated unique capabilities in the treatment of industrial wastewaters such as the separation of oil from water, reduction of toxic compounds present in the wastewater and recovery of valuable byproducts. Nevertheless, the process is unattractive to small-scale industries due to high operating and capital costs. [3]

SECONDARY TREATMENT - CLARIFICATION

The Secondary Treatment consists of at least two types of systems. The first is Fixed Film / Media System and the second is Suspended Growth Systems.

The Fixed Film / Media Biological Oxidation System has a media in which the Biological Film is attached to a Media. The Waste Water is slowly passed through the Media and the Biological Film degrades the organics to non-organic products. The fixed film system include Trickling filters, Rotating Biological Contactor (RBC), etc.

The Suspended Growth Biological Oxidation System includes Stabilization Ponds, Single Pass Aerated Lagoons and Activated Sludge Systems.

BIOLOGICAL OXIDATION

One of the most common ways to convert soluble organic matter to insoluble matter is through biological oxidation. Soluble organics metabolized by bacteria are converted to carbon dioxide and bacterial floc, which can be settled from solution.

The biodegradable contaminants in water are usually measured in terms of biochemical oxygen demand (BOD). BOD is actually a measure of the oxygen consumed by micro organisms as they assimilate organics.

Bacteria metabolize oxygen along with certain nutrients and trace metals to from cellular matter, energy carbon dioxide, water and more bacteria. This process may be represented in the form of a chemical reaction. [1]

The purity of the water depends on minimizing the amount of organic compounds that remain after secondary treatment. Factors that affect biological oxidation are shown in Table 2. [1]

Food (Organic compounds)
+Microorganisms
+Oxygen
+Nutrients
®
Cellular Matter
+Microorganisms
+Carbon dioxide
+Water
+Energy

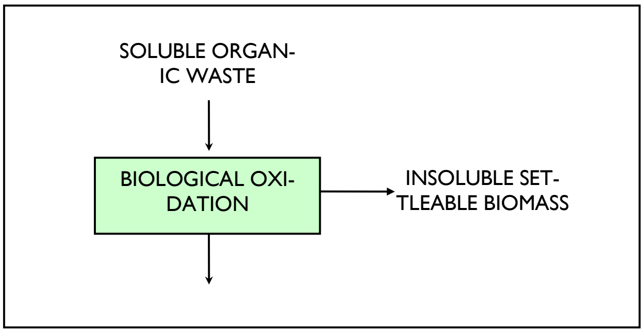
Table 2 - Factors Affecting Biological Oxidation

Factor	Affect
Food, BOD	To maintain control with efficient BOD removal, the proper amount of food must be supplied
Dissolved Oxygen	Insufficient oxygen levels inhibit BOD removal
pH, toxicants	With time, bacteria adapt to change in conditions. Rapid changes in pH or type of waste organic inhibit the process
Time	The degree of degradations varies with time
Nutrients	Bacteria require trace amounts of nitrogen and phosphorus for cell maintenance.
Temperature	Low Temperature result in slow reaction rates, higher temperature may kill many strains of bacteria

Figure 2 - Biological oxidation converts soluble waste to clean water and insoluble biomass

FIXED FILM / MEDIA SYSTEMS

Fixed Film / Media Oxidation passed influent wastewater across a substructure laden with fixed biomass. Fixed media allow a biological layer to grow on a substructure continually exposed to raw wastewater. As the layer grows in thickness oxygen transfer to the inter-most layers is impeded. Eventually, some of the layer is removed. This phenomenon is called sloughing. In a continuous process this material is carried to a sedimentation stage, where it is removed.



Media plugging and lack of oxygen transfer are the primary difficulties encountered with fixed media designs. Plugging problems can be alleviated by increase wastewater shear. This is normally accomplished by recycling a portion of the wastewater. The graphical representation of bio-film formations in the fixed film/ media system is shown in Figure 3.

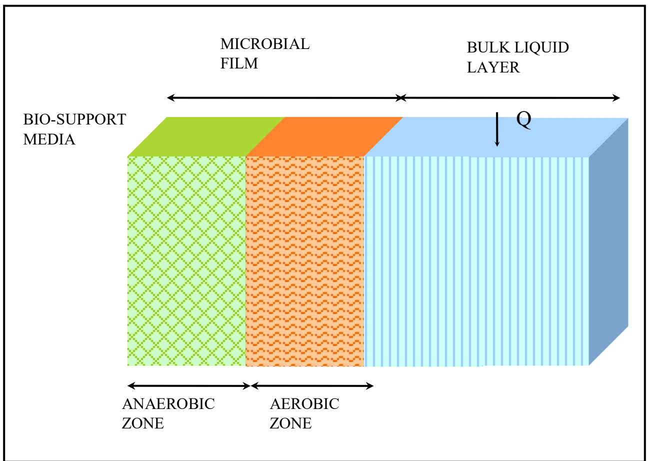


Figure 3 - Volumetric element for Microbial film and Bulk Liquid Layers in the fixed film/media system

SUSPENDED GROWTH BIOLOGICAL OXIDATION SYSTEMS

ACTIVATED SLUDGE SYSTEMS

Activated sludge system is a biological process that is characterized by the suspension of aerobic microorganisms being maintained in a relatively homogenous state by the mixing or turbulence induced from the aeration process [(3)].

The microorganisms oxidize the soluble and colloidal organics in the presence of molecular oxygen. In the oxidation process, a part of the organic material is transformed into new cells that subsequently undergo auto-oxidation in the aeration basin.

In the conventional activated sludge process, the typical hydraulic retention time (HRT) is in the range of 6 to 10 hours, and the volumetric loading rate (VLR) of the reactor is in the range of 0.32 to 0.64 kg BOD /m^3.day.

In the process, the flocs generated from the oxidation process are separated in a clarifier and partly recycled into the aeration basin with some removed for disposal off site or further treatment. The supernatant overflows from the clarifiers as final discharge. The process has been widely used throughout the world as one of the most proven method to treat, not only sewages but also highly toxic industrial wastewaters. Since its invention, the process has been modified to improve its efficiency and reduce the capital and operation costs. [(3)]

The advantages of the activated sludge process are as follows:

- Requires limited space – HRT is 3 to 36 hour range
- MLSS is in the range of 1500 to 10,000 mg/l
- Reliable operator control capability
- Can handle shock loads better with less recovery time required
- Can handle high loaded waste streams
- Excellent solids removal capability

The control of contaminate oxidation at high BOD loading requires a bacteria population that is equal to the level of food. The need is the basis for the activated sludge process. In the activated sludge process, reactants, food, and microorganism are mixed in a controlled environment to optimize BOD removal. The process incorporates the return of concentrated microorganisms to the influent waste.

When bacteria are separated from wastewater leaving an aeration basin and re-introduced to the influent, they continue to thrive. The re-circulated bacteria continue to oxide wastewater contaminates, and if present in sufficient quaintly, produce a relatively low BOD effluent water. Because the activated sludge process incorporates the return of concentrated microorganisms, it must include a process for microorganism concentration and removal. This process includes an aeration stage and a sedimentation stage.

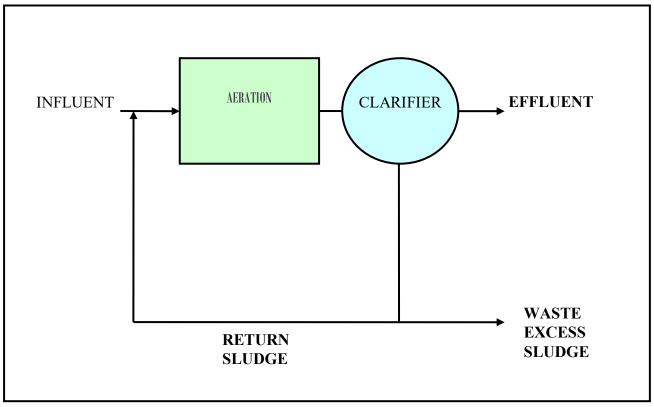


Figure 4 - Activated sludge process returns active biomass to enhance waste removal

The operating parameters that affect the performance of any activated sludge process are BOD, microorganism, dissolved oxygen, retention time, nutrient concentration, and external influences of temperature and pH. In order to understand the various activated sludge designs, it is necessary to examine the relationship between available food and bacteria population.

Initially, excess food is present; therefore the bacteria reproduce in a geometric fashion. This is termed the "log growth phase". As the population increase and food decrease a plateau is reached in population. From the inflection point on the curve to the plateau, population is increasing but a decreasing rate. This is called the "declining growth phase".

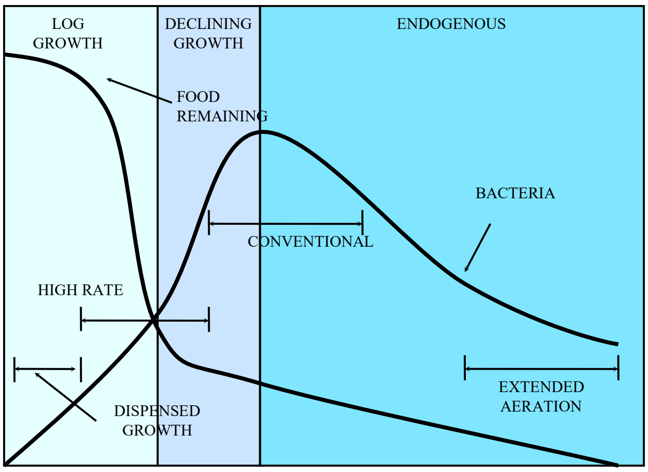


Figure 5 - Model of bacteria population as a function of time and amount of food

Once the plateau is crossed, the bacteria are actively competing for the remaining food. The bacteria begin to metabolize stored materials, and the population decreases. This area of the curve is termed "endogenous respirations". Eventually, the bacterial population and the DOD are at a minimum.

Because activated sludge is a continuous, steady sate process, each plant operates at some specific point on the curve, as determined by the oxidation time provided. The point of operation determines the remaining bacteria population and BOD of the effluent.

Optimization of an activated sludge plant requires the integration of mechanical, operational and chemical approaches for the most practical overall program.

Mechanical problems can include excessive hydraulic loading, insufficient aerations, and short-circuiting. Operational problems may include spill and shock loads, pH shocks, failure to maintain correct mixed liquor concentrations, and excessive sludge retention in the clarifier. Because activated sludge depends on microorganism re-circulation, sedimentation is the key stage. The settle ability of the biomass is a crucial factor. As bacteria multiply and generate colonies, they excrete natural biopolymers. These polymers and the slime layer that encapsulates the bacteria influence the flocculation and settling characteristics of the bacteria colonies.

It has been determined empirically that the natural settle ability of bacteria colonies is also a function of their position on the time chart. Newly formed colonies in the log growth phase are relatively non-settle able. At the end of the declining growth phase and the first part of the endogenous phase, natural flocculation is at an optimum. As the endogenous phase continues, colonies break up and floc particles are dispersed, decreasing the biomass settle ability.

Although microbes are eventually able to break down most complex organics and can tolerate very poor environments, they are very intolerant of sudden change is pH, dissolved oxygen and the organic compounds that normally upset and activated sludge system. These upsets normally result in poor BOD removal and excessive carry over of suspended solids (unsettled microorganisms) in the final effluent.

TYPES OF ACTIVATED SLUDGE SYSTEMS [4]

1. Conventional, plug flow systems

The most common activated sludge design used by municipalities and industry operates in the endogenous phase, in order to produce and acceptable effluent in BOD and TTS levels.

Conventional aeration represents a "middle of the road" approach because its capital and operating cost are higher than those of the high rate process, but lower than those of the extended aeration plants. Natural flocculation is at the optimum, so the required sedimentation time for the removal of suspended solids from the effluent is minimized. (1)

Settled wastewater and return activate sludge (RAS) enter the front end of the aeration tank and are mixed by diffused air or mechanical aeration. In early designs, air application was generally uniformed throughout the tank length; however, low DO concentrations usually occurred in the initial passes of the tank. In modern designs, the aeration system is designed to match the oxygen demand along the length of tank by tapering the aeration rates. During the aeration period, adsorption, flocculation, and oxidation of organic matter occur. Activated sludge solids are separated in a secondary settling tank. (4)

2. Extended Aeration, plug flow systems

Extended aeration plants operate in the endogenous phase, but use longer periods of oxidation to reduce effluent BOD levels. This necessitates higher capital and operating cost (i.e., larger basins and more air). In conjunction with lower BOD, extended aeration produces a relatively high-suspended solids effluent when optimum natural settling ranges are exceeded.

Extended aeration design may be necessary to meet effluent BOD requirements when the influent is relatively concentrated in BOD or the waste are difficult to biodegrade. Because extended aeration operates on the declining side of the biomass population curve, net production of excess solids is minimized.

Therefore, savings in sludge handling and disposal cost may offset the higher pant capital and operating cost required for extended aeration. (1)

The extended aeration process is similar to the conventional plug-flow process except that is operates in the endogenous respiration phase of the growth curve, which requires a low organic loading and long aeration time. Because of the long HRT (in the order of 24 to 36 hours), aeration equipment design is controlled by mixing needs and not oxygen demand. The process is used extensively for pre-engineered plants for small communities. Generally, primary clarification is not used. Secondary clarifiers are designed at lower hydraulic loading rates than conventional activated sludge clarifiers to better handle large flow rate variations of small communities. Although the bio-solids are well stabilized, additional bio-solids stabilization is required to permit beneficial reuse. (4)

3. Complete Mix Systems

The complete mix activated sludge (CMAS) is an application of the flow regime of a continuous flow stirred-tank reactor. Settled wastewater and RAS are introduced typically at several points in the aeration tank. The organic load, MLSS concentration and oxygen demand are uniform throughout the tank. An advantage of the CMAS is the dilution of shock loads that occurs in the treatment of industrial wastewaters. The CMAS is relatively simple to operate but tends to have low organic substrate concentrations that encourage the growth of filamentous bacteria, causing sludge bulking problems

4. Contact Stabilization

Due to the highly efficient absorptive capabilities of activated biomass, the time necessary for biomass to capture the colloidal and soluble BOD is approximately 30 minutes to one hour. Oxidation of fresh food requires the normal aeration time of 4-8 hours. IN the contact stabilization design, relatively quick sorption time reduces aeration tank volume requirements. The influent waste is mixed with return biomass in the initial aeration tank (or contact tank) for 30-90 minutes. The entire flow goes to sedimentation, where the biomass and its captured organics are separated and returned to a re-aeration tank. In the re-aeration tank the wastes under go metabolism at a high biomass population. The system is designed to reduce tank volume by containing the large majority of flow for a short period of time.

This process is not generally as efficient in BOD removal as the conventional plant process, due to mixing limitation in the contact basin. Operating costs are equivalent. Due to the un-stabilized state of the biomass at sedimentation, flocculation is inferior. Suspended solids in the effluent are problematic.

Because this design exposed only a portion of the active biomass to the raw effluent at a time, it is less susceptible to feed variations and toxicants. For this reason it can be beneficial for treatment of industrial wastes. (1)

The contact zone detention time is relatively short (30 to 60 minutes), and the MLSS concentration is lower than in the stabilization zone. Rapid removal of soluble BOD occurs in the contact zone, and colloidal and particulate organics are captured in the activated sludge floc for degradation later in the stabilization zone.

In the stabilization zone, RAS is aerated and the detention time is in the order of 1 to 2 hours to maintain a sufficient SRT (solids retention time) for sludge stabilization. Because the MLSS concentration is so much higher in the stabilization zone, the contact stabilization process requires so much less aeration volume than CMAS or conventional plug flow process for the same SRT. The process was developed for BOD removal and the short contact time limits the amount of soluble BOD degraded and NH4-N oxidation. (4)

5. Step Feed

In a plug flow basin, the head of the basin receives the waste in its most concentrated form. Therefore, metabolism and oxygen demand are greatest at that point. As the waste proceeds thought the basin, the rate of oxygen uptake (respiration rate) decreases, reflecting the advanced stage of oxidation.

Tapered aeration and step aeration reduce this inherent disadvantage. Tapered aeration provides more oxygen at the head of the basin and slowly reduces oxygen supply to match demand as waste flows through the basin. This results in better control of the oxidation process and reduced air cost.

Step aeration modifies the introduction of influent waste. The basin is divided into several stages, and raw influent is introduced to each stage proportionally.

All return microorganisms (sludge) are introduced at the head of the basin. This design reduces aeration time to 3-5 hours, while BOD removal efficiency is maintained. The shorter aeration time reduces capital expenses because a small basin can be used.

Process	Aeration Retention Time, hrs	MLSS, ppm	DO ppm	Sludge Recycle %	BOD Load-ing Lb/ mft3	F/M Lb BOD / lb MLVSS	Sludge Produc-tion	BOD Re-moval %
High Rate	0.5-3	300 - 1000	0.5-2	5- 15	2.5	1.5 – 5.0	0.65 – 0.85	75-85
Conventional	6 – 8 (diffused) 9-12 (mechanical)	1000 – 3000	0.5-2.0	20-30	20-40	0.2-0.5	0.35-0.55	85-90
Extended Aeration	18-35	3000 - 6000	0.5-2.0	75-100	10-25	0.03-0.15	0.15-0.20	90-95
Step Aeration	3-5	2000 - 3500	0.5-2.0	25-75	40-60	0.2-0.5	0.35-0.55	85-95
Contact Stabilization	3-6	1000 -3000 (aeration) 4000–10000 (contact basin)	0.5-2.0	25-100	60-70	0.2-0.6	0.35-0.55	85-95
Pure Oxygen	1-3	3000-8000	2-6	25-50	100-250	0.25-1.0	0.35-0.55	95-98
Complete Mix	3-5	3000-6000	0.5-2.0	25-100	50-120	0.2-0.6	0.35-0.55	85-95

Table 3 - Activated Sludge Systems (1)

Operating costs are similar to those of a conventional plant. [1]

Flexibility of the operation is one of the important features of this process because the apportionment of the wastewater feed can be changed to suit operating conditions. The concentration of MLSS may be as high as 5000 to 9000 mg/l in the first pass, with lower concentrations in subsequent passes as more influent feed is added. This process has the capability of carrying a higher solids inventory and thus a higher SRT for the same volume as a conventional plug flow process. [4]

6. Oxidation Ditch

Oxidation ditch consists of a ring or oval -shaped channel equipped with mechanical aeration and mixing devices. Screened wastewater enters the channel and is combined with the RAS. The tank configuration and aeration and mixing devices promote unidirectional channel flow, so that the energy used for aeration is sufficient to provide mixing in a system with a relatively long HRT. The aeration/mixing method used creates a velocity from 0.25 – 0.30 m/s in the channel, which is sufficient to keep the activated sludge in suspension. At these channel velocities, the mixed liquor completes a tank circulation in 5 –15 minutes, and the magnitude of the channel flow is such that it can dilute the influent wastewater by a factor of 20-30. As a result, the process kinetics approach that of a CMAS, but with pug flow along the channel.

7. High -Purity Oxygen

A staged enclosed reactor is used in the high-purity oxygen. Three or four stages are generally used and the influent wastewater, RAS and high-purity oxygen are added to the first stage. The oxygen partial pressure in the headspace may range from 40 to 60 percent in the first stage to 20 percent in the last stage. At high oxygen partial pressure, higher volumetric oxygen transfer rates are possible so that pure oxygen systems can have a higher MLSS concentration and operate at a shorter HRT and higher VLR than conventional processes. The rate of oxygen addition is 2 to 3 times greater than CAS. Major advantages for pure oxygen systems are the reduced quantities of off-gas if odor control and VOC control are required.

8. Sequential Batch Reactors (SBR)

The SBR is a fill-and-draw type of reactor system involving a single complete-mix reactor in which all steps of the activated sludge process occur. An SBR goes through a number of cycles per day; a typical cycle may consist: fill, aeration, settle and withdrawal of supernatant.

An idle step may also be included to provide flexibility at high flows. Mixed liquor remains in the reactor during all cycles, thereby eliminating the need for separate secondary clarifiers. The HRT ranges from 18 to 30 hours, based on influent flow rate and tank volume used.

LATEST RESEARCH IN WASTEWATER TREATMENT SYSTEMS

Recently, biological process has been a ttracting considerable attention for removing heavy metals from aqueous wastes. Biofilm systems, in particular, are able to retain relatively high biomass concentrations resulting in shorter liquid detention times, better performance stability and higher volumetric removal rates. The efficiency of an expanded bed biofilm reactor in the treatment of waste waters contaminated with heavy metals has been investigated for rubber product manufacturing industry. In the study, it has been found that the process could achieve 60% to 90% removal of Zinc.

Application of plant-based flocculants can be considered as new in industrial wastewater treatments. Despite its biodegradable characteristics, plant-based flocculants possess an advantage for oxidation and coagulation process. A newly invented plant-based flocculants, namely KN2 has been introduced in the treatment of inking wastewater.

Comparison has also been made with other conventional chemical-based flocculants (i.e. PAC, PE, PDMC, etc.) in order to compare their effectiveness in removing pollutants. Application of activated carbon as a polishing media at the final stage shows a drastic declination in COD and BOD values as well as the other parameters.

Dissolved Air Flotation (DAF) using micro-bubbles of size 50μm are used to remove suspended solids, emulsified oils & greases from industrial and municipal waste waters. Micro-sized air bubbles are formed by injection of pressurised recycle water into a flotation tank using special designed nozzles or needle valves. These bubbles will attach to the suspended solids and float them to the surface. The floated sludge can be removed either by overflow or mechanical scraping. Influencing parameters being studied are bubble size, particle size, air pressure for saturated vessel, air saturation system, and efficiency of suspended solids removal. The saturation system consists of an unpacked saturation vessel, an air compressor and the associated control system. The saturation vessel operated at a 4 bars pressure. The results of the study have reported that percentage removal of Suspended Solids, COD, Colour and Turbidity were 90%, 91%, 86% and 90%, respectively. Simulation has been carried out to obtain kinetic data for the parameters under study.

CONCLUSIONS

The Waste Water Treatment System has a variety of unit operations. They include gravity separators, mechanical separators, filters, stripper towers, aeration and clarifier basins, as well as others. The transformation of the by-product streams is based of the effectiveness of each of these unit operations.

Each of these unit operations has three values.

1. Industry Standard Design Value
2. Actual Design Value and
3. Present Operating Value

The difference between the values can be benchmarked to establish areas good operation and areas of opportunities for improvements. A review of the individual unit operations should be conducted to maximize the effectiveness of a Waste Water Treatment System.

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Process	Process Influent	BOD	COD	TOC	SS	Oil	Phenol	NH3	Sulfide
API Separator	Raw Water	5-40	5-30		10-50	60-99	0-50		
Primary Clarifier	API Effluent	30-60	20-50		50-80	60-95	0-50		
DAF	Separator Effluent	20-70	10-60		50-85	70-85	10-75		
Filter	API Effluent	40-70	20-55		75-95	65-90	5-20		
Secondary Oxidation Pond	API Effluent	40-95	30-65	60	20-70	50-90	60-99	0-15	70-99
Aerated Lagoon	Primary Effluent	75-95	60-85		40-65	70-90	90-99	10-45	95-99
Activated Sludge	Primary Effluent	75-95	60-85		40-65	70-99	90-99	10-45	95-99
Trickling Filter	API Effluent	60-85	30-70		60-85	50-80	70-98	15-90	70-99
Cooling Tower	Primary Effluent	50-95	40-90	10-70	50-85	60-75	75-99	60-95	
Activated Carbon	Primary Effluent	70-95	70-90	50-80	60-90	75-95	90-99	7-33	
Tertiary Filter granular media	Secondary Effluent			50-65	75-95	65-95	5-20		
Activated Carbon	Secondary + Filter Effluent	91-98	86-94	50-80	60-90	70-95	90-99	33-87	

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