HERITAGE INSTITUTE OF TECHNOLOGY, KOLKATA

DEPARTMENT OF CHEMICAL ENGINEERING

presents

CHEMEDGE

Winter Edition
2023

FEATURING

- Technical Essays
- Chemspark 2023
- Creative Writing
- Reconnection
- Shutter Stock
- Artistic Canvas
- Class Photograph

6th Edition

chem.edge

ChemEdge

HERITAGE INSTITUTE OF TECHNOLOGY

Principal Sir Speaks

I am delighted to know that students of the Department of Chemical Engineering of HITK are set to publish Chemedge, a departmental publication. Chemedge will contain contributions of teachers and students of the department on subjects of Chemical Engineering.
Any branch of engineering today goes through rapid changes. Problems are more interdisciplinary in nature and subjects need continuous upgradation. Students have to understand and continuously strive to learn newer subjects and approaches.
Chemedge goes beyond curricula and informs all the stakeholders the trajectories of change.
I congratulate all concerned for making such a brilliant effort to bring out this publication.
My good wishes to all.

Prof.(Dr.) Basab Chaudhuri
Principal
Heritage Institute of Technnology

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HOD Ma'am Speaks

I feel proud to share the winter edition of Chemedge 2023. One full year has rolled by and the editorial team has changed hands to make way for the new. I see new faces, bright as they were last year, eager to take on responsibility, very optimistic. Chemedge is as much of a technical journey as a creative one. And definitely a documentary of HIT Chemical Engineering Department's enlarging pool of alumni. Each version gets better in content and creative effort. I thank all everyone who contributed to this effort. I sincerely appreciate the team effort as I see that every version of Chemedge outbeats its previous one.

Sulagna Chatterjee

Prof.(Dr.) Sulagna Chatterjee
HOD, Chemical Engineering
Heritage Institute of Technnology

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From Mentors' Desk

It is our proud privilege to announce the publication of winter issue of CHEMEDGE, the biannual Students' e-magazine of Chemical Engineering Department of Heritage Institute of Technology, Kolkata. Students are encouraged to contribute technical articles based on latest challenges and recent innovations as well as developments in the field of Chemical Engineering and allied disciplines that could solve real world problems. This platform ignites the young minds of students for quest of cutting edge scientific and technical advancements, not only confined in the fields to Chemical Engineering but in other interdisciplinary areas as well. Apart from technical articles students are also enthusiast to showcase their talents in various extracurricular activities including various forms of literary arts, photography, sketching etc.

This magazine also gives a brief overview of various departmental academic events namely Industry visits held in this year 2023 and ChEMSPARK-2023. ChEMSPARK is basically an event based on students' initiative and active participation. In this year, a cluster of students' competitions such as essay writing, Autocad drawing and technical quiz etc. alongwith technical deliberations of invited external experts have been organized in ChEMSPARK.

We appreciate sincere efforts of our excellent student editorial team for their involvement and dedication for successful publication of winter issue of the Magazine.

Dr. Diptendu Datta
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Dr. Sangita Bhattacharjee
Assistant Professor
Department of Chemical Engineering

HERITAGE INSTITUTE OF TECHNOLOGY

Message From The Editorial Board

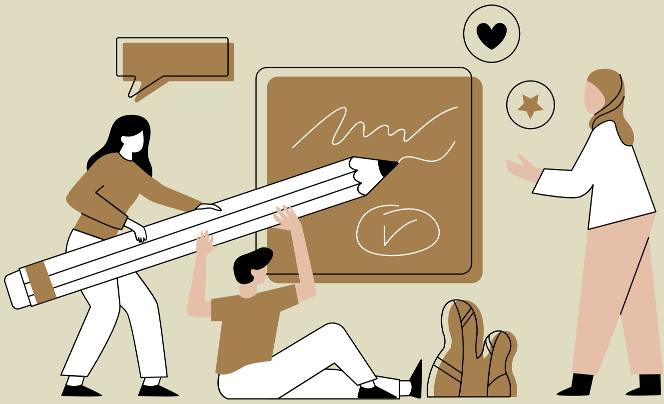
We, the students of the Department of Chemical Engineering at Heritage Institute of Technology, Kolkata, take great pride in presenting the winter edition of ChemEdge 2023, our biannual departmental magazine. The Editorial Board, composed of dedicated student editors and our PR team, extends its heartfelt gratitude to our mentors, Professor Diptendu Dutta and Professor Sangita Bhattacharjee. Their guidance and unwavering support have been instrumental in the successful publication of this edition.

This issue features a captivating array of technical articles contributed by students within our department. Additionally, it proudly showcases the outstanding technical essays from the ChEMSPARK 2023 essay competition. Much like its predecessor, this edition boasts a creative section replete with imaginative literature, photography, and artwork, alongside messages from our esteemed alumni.

We sincerely hope that our readers will derive as much enjoyment from exploring this magazine as we have experienced in its creation.

Thanking You,
Student Editorial and PR Team

TABLE OF CONTENTS



Technical Article from Our Valued Alumni 7

Technical Article 10

Essays from Chemspark’23 110

Departmental Events 137

Creative Writing 146

Shutter Struck 151

Artistic Canvas 156

Reconnection 160

Class Photographs 163

Credits 166

Technical Article from Our Valued Alumni

Basic Background into Green Hydrogen in perspective of Indian Oil Refineries

India as an emerging economic superpower is a net importer of Crude Oil which contributes a good chunk of its Import Energy Mix. In the fiscal Year 2022-23, India's net Crude Oil import went up to above 230 Million Tonnes accounting for a Foreign Exchange of around $ 157-160 Billion, (As per PPAC & MoPNG Data available in Public Domain. While efforts are on to reduce the dependence in line with GOI "Atmanirbhar Bharaat" Initiative recent geopolitical developments like Russia-Ukraine conflict as well as Western sanctions makes Oil & Gas Import very susceptible to Price Volatility.

Indian Refineries have traditionally been bulk importers of Middle-Eastern as well as South-East Asian Crudes along with our very own Bombay High (BH) Crude. While a lot of technical & Logistical factors are considered before arriving at a consensus on the type of Crude to be processed to derive all the Petroleum & petrochemical Products for a given period (usually fortnightly , monthly or Quarterly); very often it is the burden on the Public Exchequer which outweighs all other considerations.

India as a nation also has an obligation to do whatever it can to bring down the overall Carbon Footprint; in line with the PAris Climate Agreement to which our Nation is fully committed. While Industries from all Sectors under the guidance and support of their respective Ministries are doing their bit, one such initiative that is of paramount importance in context of Oil & Gas Industry and particularly the Indian Refineries is the "National Green Hydrogen Mission" launched in Jan-2022.

Oil Refineries have always been using Hydrogen produced from either the process of "Steam Reforming of Natural Gas / Naphtha" or "Platforming of Naphtha to produce high Octane Gasoline Stream". Both these Processes falls under the category of Grey Hydrogen which has a net positive Carbon Footprint into the Environment.

Green Hydrogen is produced using electrolysis of water with electricity generated by renewable energy. The carbon intensity ultimately depends on the carbon neutrality of the source of electricity (i.e., the more renewable energy there is in the electricity fuel mix, the "greener" the hydrogen produced).

India aims to achieve a capacity of 5 Million Metric Tons (MMT) of Green Hydrogen Capacity by the Year 2030-31 as envisaged under the motto of National Green Hydrogen Mission. This will go a long way in reducing Indian Refineries Net Carbon Footprint without having an adverse impact on the Fuel Economics since a higher Cost of Production of Petroleum Products in the Refineries will directly result in a higher Retail Price; which is not welcomed in a Price Sensitive Market like India due to the Cascading effect it has on a large number of other Businesses/ Industries and to the Public in general.

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TECHNICAL ARTICLES

The Chaos Conundrum: Butterfly Effect and the Boundaries of Prediction

In chaos theory, the butterfly effect is the sensitive dependence on initial conditions in which a small change in one state of a deterministic nonlinear system can result in large differences in a later state.

The term is closely associated with the work of mathematician and meteorologist Edward Lorenz, in his paper titled, “Deterministic Nonperiodic Flow” published nearly 50 years ago. He noted that butterfly effect is derived from the metaphorical example of the details of a tornado (the exact time of formation, the exact path taken) being influenced by minor perturbations such as a distant butterfly flapping its wings several weeks earlier. This, perhaps more than any other recent scientific concept, has captured the public imagination.

The very reason people are so fascinated by the butterfly effect is because it gets at a fundamental question, which is,

How well can we predict the future?

This article thus, is an attempt to answer that question by examining briefly some of the different scientific approaches behind the butterfly effect and how it led to such a change of perception about chaos with direction of time. Much of this is explained by visual and practical application concepts, and extensive use of Mathematics is avoided; so, it is also understandable by people who do not have a background of intricate Mathematical methodology.

Going back to the late 1600s, after Isaac Newton formulated his laws of motion and universal gravitation, everything seemed predictable. People could explain the motions of all the planets and moons, could predict eclipses and the appearances of comets with pinpoint accuracy by centuries in advance. French physicist Pierre-Simon Laplace summed it up in a famous thought experiment:

He imagined a super-intelligent being, now called "Laplace's Demon", that knew everything about the current state of the universe: the positions and momenta of all the particles and how they interact. He concluded, if this intellect were vast enough to submit the data to analysis, then the future, just like the past, would be present before its eyes. This is total determinism- the view that the future is already fixed, and one would just have to wait for it to manifest itself.

Let us consider the case of a simple pendulum here, to introduce an important representation of dynamical systems, which is phase space. We make a 2D plot that represents every possible state of the pendulum, i.e., every possible thing it could do in one graph. On the x-axis we plot the angle of the pendulum, and on the y-axis its velocity.

This is what is called phase space.

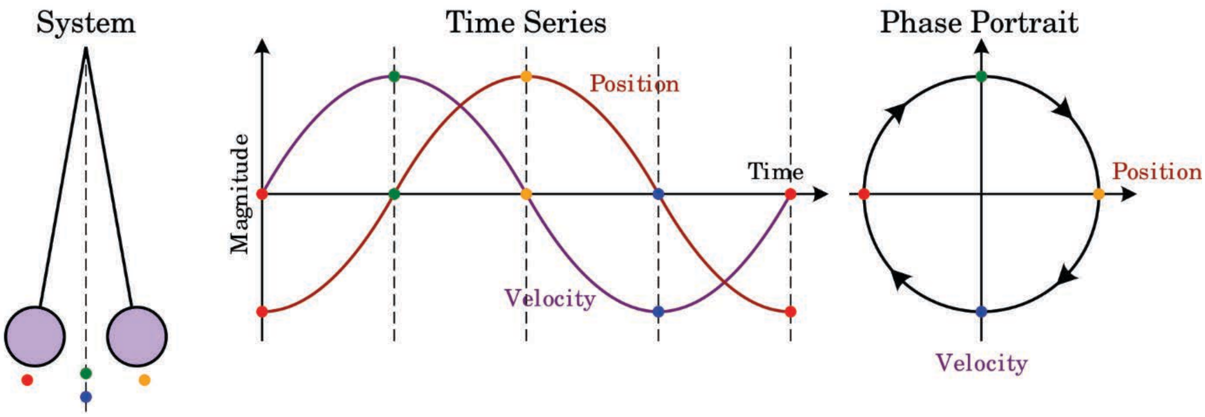

Figure 1: Illustration showing the method of construction of phase space for a simple pendulum

If the pendulum has friction, it will eventually slow down and stop and this is shown in phase space by the inward spiral - the pendulum swings slower and less far each time and no matter what the initial conditions are, we know that the final state will be the pendulum at rest hanging straight down. From the graph shown in Figure 3, it looks like the system is attracted to the origin, that one fixed point, and hence this is called a fixed-point attractor.

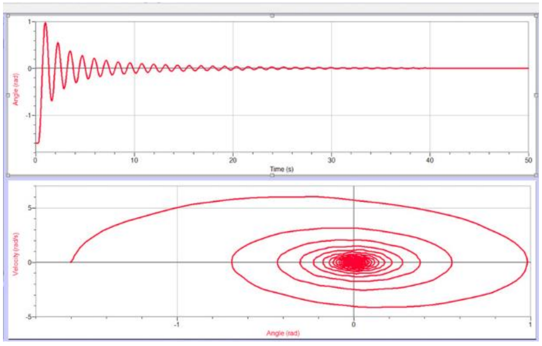

Figure 2: i) Angular displacement-time graph and ii) phase space for a simple pendulum exhibiting damped oscillations. The central point in the space, where the spiral converges, is the fixed-point attractor for this system.

Note: there exists a quadratic dependence of the damping torque on the angular velocity in this case.

If the pendulum does not lose energy, it will swing back and forth the same way each time, and in phase space we get a loop as shown Figure 3. The pendulum is going fastest at the bottom but the swing is in opposite directions as it goes back and forth.

The closed loop tells us the motion is periodic and predictable and anytime an image like this is seen in phase space, we know that this system regularly repeats. We vary the amplitude of the pendulum under the same conditions, but the picture in phase space is very similar: just a different sized loop.

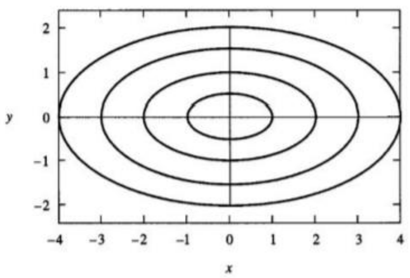

Figure 3: Phase-space of a simple pendulum with no damping. The concentric ellipses signify the variation of amplitude of vibration considered for study.

An important thing to note is that the curves never cross in phase space and it is because each point uniquely identifies the complete state of the system, and that state has only one future. So, an inference can be drawn that once we have defined the initial state of this dynamical system, the entire future is determined.

The above case of the pendulum can be well understood using Newtonian Mechanics, but Newton himself was aware of problems that did not submit to his equations so easily, particularly the three-body problem. It meant calculating the motion of the Earth around the Sun was simple enough with just those two bodies but if we add in one more body, like the moon, solving the equation of motion became virtually impossible. This problem, as would become clear to Henri Poincaré two hundred years later, was that there was no simple solution to the three-body problem. Poincaré had glimpsed what later became known as chaos.

Chaos really came into focus in the 1960s, when meteorologist Edward Lorenz tried to make a basic computer simulation of the Earth's atmosphere. He formulated 12 equations and 12 variables, like temperature, pressure, humidity, etc., and the computer would print out each time step as a row of 12 numbers, and so one could watch how they evolved over time. The breakthrough came when Lorenz wanted to redo a run, but as a shortcut he entered the numbers from halfway through a previous printout and then he set the computer calculating. The new run followed the old one for a short while but then it diverged and pretty soon it was describing a totally different state of the atmosphere- that meant a totally different weather.

The real reason for the difference came down to the fact that printer rounded to three decimal places, whereas the computer calculated with six. So, when he entered those initial conditions, the difference of less than one part in a thousand created totally different weather just a short time into the future.

Lorenz concluded from this observation that even if he changed the numbers just a tiny bit, results diverged dramatically. This system displayed what's become known as sensitive dependence on initial conditions, which is the hallmark of chaos.

These systems are completely deterministic, just like the pendulum because if one could input exactly the same initial conditions, they would get exactly the same result. However, problem is, unlike the pendulum, this system is chaotic; so, any difference in initial conditions, no matter how tiny, will get amplified to a totally different final state. It seems like a paradox, as this system is both deterministic and unpredictable, because in practice, it is impossible to know the initial conditions with perfect accuracy, to an infinite decimal place.

Now far from being the exception to the rule, chaotic systems have been turning up everywhere; it is commonly seen in the behaviour of a waft of smoke or ocean turbulence. Even our solar system is not predictable and studies have simulated our solar system for a hundred million years into the future have found its behaviour as a whole to be chaotic, with a characteristic time of about four million years. That means within, say 10 or 15 million years, some planets or moons may have collided or been flung out of the solar system entirely.

Thus, the very system we think of as the model of order, is unpredictable on even modest timescales.

Which brings us back to the initial question: So how well can we predict the future?

We cannot predict accurately at all, at least when it comes to chaotic systems. The further into the future we try to predict the harder it becomes and past a certain point, predictions are no better than guesses. The same is true when looking into the past of chaotic systems and trying to identify initial causes. Thus, Chaos puts fundamental limits on what we can know about the future of systems and what we can say about their past.

If we start with a whole bunch of different initial conditions in Lorenz's equations and watch them evolve, initially the motion is messy. But soon all the points have moved towards or onto an object which, coincidentally, looks a bit like a butterfly. For a large range of initial conditions, the system evolves into a state on this attractor. All the paths traced out here never cross and they never connect to form a loop, since, if they did then they would continue on that loop forever and the behaviour would be periodic and predictable. Hence, each path is actually an infinite curve in a finite space, which is possible by the concept of Fractals. This particular attractor is called the Lorenz attractor, which is probably the most famous example of a chaotic attractor though many others have been found for other systems of equations.

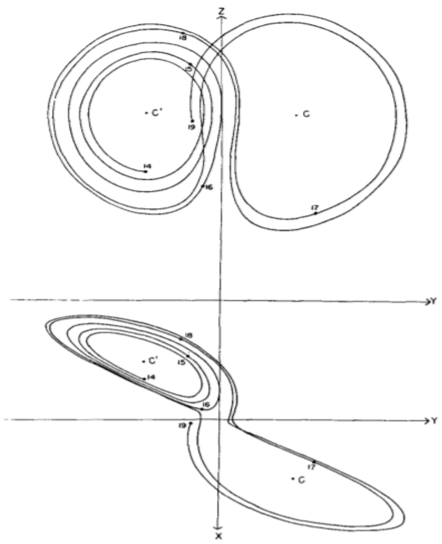

Figure 4: Numerical solution of the convection equations of Lorenz by projections on the YZ and XY planes. The curves are infinite and non-intersecting in such finite planes, showing the behaviour becomes chaotic with time

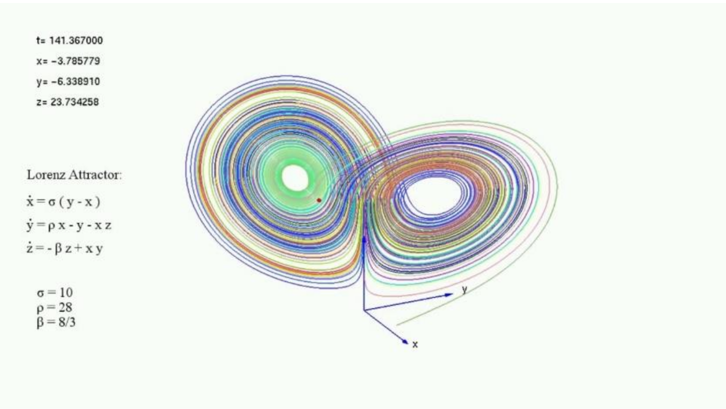

Figure 5: Graphical illustration, showing the Lorenz Attractor for a particular set of equations. The picture coincidentally resembles a butterfly itself

In conclusion, the most common opinion heard about the butterfly effect, is usually about how tiny causes make the future unpredictable. But the science behind the butterfly effect also reveals a deep and beautiful structure underlying the dynamics. One that can provide useful insights into the behaviour of a system. We cannot predict how any individual state will evolve, but it is possible say how a collection of states evolves and, at least in the case of Lorenz's equations, they take the shape of a butterfly.

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THE CHANGING FACE OF ENERGY: MOVING BEYOND OIL AND GAS

Imagine there are billions of us on this big, beautiful planet, and we're all having a pretty awesome life, thanks to one magical thing: Oil. We use oil for so much stuff! It's not just about making our cars go zoom or keeping our homes warm. Nope, it's behind everything we enjoy, like our favourite fast-food burgers, comfy garden furniture, and even life-saving medicines. But here's the tricky part: we're using up a lot of this oil, and we're using more and more each year. It's like eating your favourite candy, and you can't stop. Now, we've already used up about half of the easy-to-find oil. So, how do we keep this good life going? Being the Chemical Engineering branch pupil, we all know, one of the most important industry we scholars are approaching is Oil and Gas. For a long time, Oil and Gas were the go-to sources of energy, driving our world forward. But continuously we are noticing the industries are bending their pitch of interest into non-oil outputs. Are our oil and gas industries slowly vanishing? Or it will change into something else? But why? Let's delve deeper about this.

Ancient organisms in ocean and swamps had soaked up the power of the sun, their fossils compressed over millions of years into coal, and a mile or more down into Natural Gas and Crude Oil. At first, burning coal, the time-capsule of the Sun's energy, and then oil came along. And that started off this kind of boom. Oil was the most energy-packed liquid source of power that you could get your hands on. Oil put the world in motion. What oil did was really create the modern world. Power plants, Refineries, Gas stations, everybody wanted to invest in oil and gas. But how could you use oil to go further and further? Here's the crazy thing: this quest for oil drives us to do all sorts of things. It can make countries come up with clever plans, like secret missions in spy movies. It even messes with the way people live in different parts of the world, sometimes not in a good way. It can help some not-so-nice leaders stay in power, and it's caused big problems like wars and conflicts.

Fig 1: Oil pump with candle stick graph chart in the background. World Oil Industry - GETTY

Paul Roberts, did some serious investigating, and he's telling us what might happen next. He says that saying goodbye to oil won't be easy. It could be a bit of a rollercoaster ride with twists and turns. But it's also a chance for a new adventure. And guess what? It'll change how we live our everyday lives, making things different, maybe even better! The author of "The End of Oil: On the Edge of a Perilous New World", points out significant challenges linked to oil. All fossil fuels, including oil, are inherently finite in quantity, leading to the well-known issue of Peak-Oil (limited amount of oil). Many affluent nations, like the United States, heavily rely on oil from politically unstable countries, particularly within OPEC, like Nigeria! (OPEC- Organization of the Petroleum exporting Countries, a group of countries that produce a significant amount of the world's oil). This can mix up oil and international politics, but people argue about how exactly they are connected. Some say oil causes conflicts like Iraq War, while others dispute such claims. Lastly, Global warming. In the mid-19th century, a scientist, named Eunice Foote, conducted an experiment. She filled one tube with regular Air, and another with Carbon dioxide, put thermometers in them, and placed in the sun. She noticed Carbon dioxide got a lot hotter & stayed hot for longer. She published her results noting that "An atmosphere of that gas would give to our earth a high temperature." Three years later, Edwin Drake struck oil in western Pennsylvania. Fast forward to the 1960s, the American Oil Industry celebrated its centennial. They invited the physicist Edward Teller, one of the inventors of the atomic bomb, to make a speech about the future of energy. “We probably have to look for additional fuel supplies”, he shocked the crowd. “Because the extra carbon emitted from burning fossil fuel causes a greenhouse effect”. Which he believed, “would be sufficient to melt the ice cap and submerge New York.” Scientists were sounding alarms. A decade later, Exxon’s own scientists were making grim predictions. By 1988, it was front page news. And since then, we kept pumping carbon dioxide into atmosphere at an accelerating rate. We have a world economy today that depends on fossil fuels for most of its energy, a third of it from Oil. Governments are starting to agree that we shouldn’t let the world warm more than +1.5°C, and we are on track to blow past that by 2030. So, why it is so hard to turn off the tap? And can we do it on time?

Today, in 2023, we’re facing the consequences. The global temperature has increased by more than 1.55°C. Heat waves are getting stronger, more frequent and more deadly. It is powering hurricanes that intensify more snappily. Wildfires are burning much greater area. The clock is ticking, and we can really wonder whether there’s any hope that we can pull this off. What’s at risk? Not the planet, it will survive. What’s at risk is us. The world emits around 50 billion tons of greenhouse gases a year, more than it ever has, and governments agreed we need to get to Net Zero (reducing man-made emissions and creating artificial carbon sinks) by 2050. This isn’t a one-size-fits-all problem. This is a very broad issue that needs lots of solutions.

Thankfully, some promising changes are underway. Wind and Solar Power are now cheaper than coal in a lot of countries. Battery Technology is improving rapidly. Governments are investing in more Hydro-Power and Nuclear Plants. Electric Cars are getting cheaper every year, and for long-haul ships and planes, chemical engineers are working in Bio-Fuels and Liquid Hydrogen. And current goal is not to get zero carbon emissions. We will produce carbon, but we will off-set it. By restoring forests, wetlands, techniques in the ocean, which can help soak up more carbon. Or carbon-capture technology, which is still expensive. Reducing methane emissions from oil and gas operations offers one of the best near-term opportunities for climate action, as the methods for mitigation are both well-established and cost-effective. We've got these nifty technologies that can cut down about 40% of those emissions without costing us a fortune. It's like turning down the volume on a noisy party without anyone noticing. We're talking about things like leak detection and repair campaigns, adding special control device to stop emissions, and swapping out parts that love to burp out methane. And here's the fun part – some of these tricks actually save us money because we can sell the captured methane. Now, the cost of these technologies can vary depending on country, prevailing emissions, labour costs and natural gas prices. Based on 2017 to 2021 cost data, with reasonable gas prices, we could cut emissions by 40% worldwide at no extra cost. But wait, when gas prices went a bit wild in 2022, we could do even better, reducing emissions by more than 60% without feeling it in our wallets. And here's the kicker: no matter what gas costs, fighting methane emissions is one of the cheapest and most effective ways to limit near-term global warming. We'd need about $100 billion to deploy all methane abatement measures in the oil and gas sector happen by 2030. Sounds like a lot, but it's actually just a tiny slice of the pie, around 3%, compared to what the oil and gas folks made in 2022.

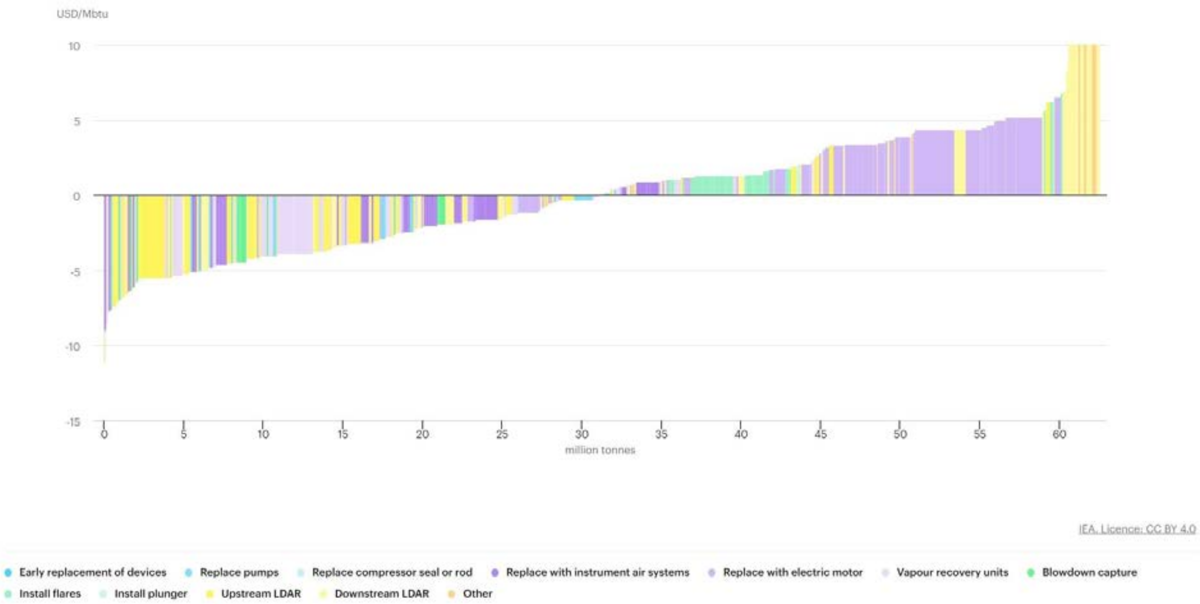

Fig 2: Marginal abatement cost curve for oil and gas methane emissions by mitigation measure, 2022 - IEA

However, here's the catch: most companies have a choice to make. But overall, the oil companies have chosen oil. Renewables make up less than one percent of their investments. One report estimates that in 2030, most of the world's oil giants will actually be producing more oil than they do today. Countries that are very economically dependent on oil, face a real challenge. The $88 trillion world economy has been based on an energy system in which oil has the preeminent role. Other energy transitions took centuries, and we're trying to change that in just 30 years- a tall order. Oil will likely stick around for a while. But it will be used by people who have no option but use oil. Developing countries, like India, are saying yes, we want to be part of this, we want transition, but we really need help. We can't achieve our climate goals if we don't achieve universal access for everybody. The story of energy, climate change, and development have to be one of the same. 30 years from now, the world will look different, but how much it will change and how different it will look that's still very hard to see. It is sometimes difficult to dream about the future and the way to get there. But a new system is possible, and that is where my hope is.

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CARBON SEQUESTRATION

Abstract:

The prospect of global warming is a matter of genuine public concern. The concentration of carbon dioxide in the atmosphere has been increasing since industrialization in the 19th century and consensus is forming that mankind is having a visible impact on the world's climate. It is generally acknowledged that the most important environmental impact of fossil fuel burning is an increased global warming from the buildup of greenhouse gases in the atmosphere. This warming occurs when added greenhouse gases trap more of the earth's outgoing heat radiations. There is a wide consensus from extensive research in the last three decades that rapid climate change is already happening, that global average temperatures are increasing at unprecedented rates. In parallel, CO2 emissions from anthropogenic sources have also been increasing in the same time frame and these are known to produce greenhouse effect. The greatest contributor to global warming over the past century has been carbon dioxide. Of all the greenhouse gases present in the atmosphere CO2 holds 82%. It is the major greenhouse gas vented to the atmosphere due to human activities. CO2 is produced mostly from deforestation, emission from subsurface reservoirs and fossil fuel burning in automobiles, industries etc. To mitigate climatic changes, it is necessary that carbon dioxide should be removed from the atmosphere. One of the methods for the removal of carbon dioxide from atmosphere is carbon dioxide sequestration also known as carbon capture and storage. In Carbon sequestration the carbon dioxide produced is captured and then stored in the geologic traps of oil and gas present in the subsurface for geologic period. Carbon sequestration consists of following steps:

1. Capturing of carbon dioxide at its source or from the atmosphere where its concentration is high.
2. Transporting the captured CO2 to the depleted oil or gas well.
3. Pumping of CO2 in the reservoir where it is stored for millions of years.

As carbon dioxide moves away from the source its concentration in the atmosphere decreases due to which the capturing of CO_2 from the atmosphere becomes very difficult. The most convenient method is to capture CO_2 at its source of formation like industrial burners etc. Following are the three methods for the capturing and separation of CO_2 from other gases:

1. Post-combustion (flue gas separation)
2. Pre-combustion
3. Oxy-fuel separation

After injection of CO_2 in the reservoir, it is trapped in the reservoir and the trapping of CO_2 can be due to:

1. Hydrodynamic trapping
2. Solubility
3. Mineralization
4. Phase trapping

Permeability is a very important parameter during Carbon sequestration. Permeability will be responsible for CO_2 that can be stored and the time which will be taken to pump it. Pressure drop in the reservoir during injection is affected by the permeability of the reservoir.

Keywords: global warming, carbon capture, carbon sequestration, combustion, injection.

Introduction:

Carbon sequestration is a pivotal process in the global carbon cycle, playing a critical role in mitigating climate change and its far-reaching impacts. It encompasses a range of natural and artificial techniques aimed at capturing and storing atmospheric carbon dioxide (CO_2) to prevent its release into the atmosphere. By harnessing various mechanisms, from photosynthesis in forests to advanced technologies like Carbon Capture and Storage (CCS), carbon sequestration offers a powerful tool to reduce greenhouse gas concentrations, stabilize the Earth's climate, and safeguard the health and resilience of our ecosystems.

Importance of Carbon Sequestration:

Climate Change Mitigation:

Carbon sequestration is a critical strategy in mitigating climate change. It directly addresses the primary driver of global warming: the increase in atmospheric carbon dioxide (CO_2) levels due to human activities, particularly the burning of fossil fuels. By capturing and storing CO_2, carbon sequestration helps reduce the concentration of greenhouse gases in the atmosphere, which in turn limits the extent of global temperature rise and minimizes the associated impacts on weather patterns, sea levels, and ecosystems.

Preserving Ecosystems:

Natural carbon sequestration processes are inherently linked to the health and resilience of ecosystems. Forests, for example, serve as substantial carbon sinks. They absorb CO_2 during photosynthesis and store it in their biomass and soil. By safeguarding and restoring natural habitats like forests, wetlands, and grasslands, we not only enhance their capacity to sequester carbon but also protect biodiversity, support wildlife, and maintain the delicate balance of ecosystems.

Enhancing Soil Fertility:

Carbon sequestration in soil, often referred to as soil carbon sequestration, is a vital component of sustainable agriculture and ecosystem health. It involves the incorporation of organic matter into the soil, which improves its physical, chemical, and biological properties. This leads to enhanced fertility, increased water-holding capacity, and improved nutrient retention. As a result, agricultural systems benefit from higher yields, reduced soil erosion, and increased resistance to droughts and other environmental stressors.

Offsetting Emissions:

As human activities continue to release CO_2 into the atmosphere through processes like energy production, transportation, and industrial activities, carbon sequestration provides a counterbalance. It allows for the capture and storage of an equivalent amount of CO_2, effectively offsetting a portion of these emissions. This helps neutralize the environmental impact of these activities and represents a crucial step towards achieving a net reduction in atmospheric CO_2 levels.

Promoting Sustainable Practices:

Carbon sequestration encourages sustainable land-use practices that align with long-term environmental goals. Afforestation, reforestation, and responsible land management not only enhance carbon sequestration efforts but also support sustainable economic activities. This includes industries like sustainable forestry, eco-tourism, and agriculture, which can contribute to local economies while simultaneously preserving and enhancing natural ecosystems.

Types of Carbon Sequestration:

Carbon sequestration encompasses various natural and artificial methods for capturing and storing carbon dioxide (CO_2) from the atmosphere. These methods can be broadly categorized into three main types:

1. Natural Carbon Sequestration:

Natural sequestration processes occur in ecosystems and geological formations without direct human intervention. They play a vital role in regulating the Earth's carbon cycle.

a. Terrestrial Sequestration:

Forests and Woodlands: Trees and vegetation absorb CO_2 during photosynthesis, storing carbon in their biomass and soil.

Grasslands and Wetlands: Extensive root systems and organic material accumulation sequester carbon in soil, especially in peatlands.

b. Oceanic Sequestration:

Phytoplankton and Algae: Marine photosynthetic organisms capture CO2 through photosynthesis, contributing to carbon uptake in the ocean.

Deep Ocean Storage: Processes like the biological pump and solubility pump transport carbon to the deep ocean, where it can remain sequestered for long periods.

2. Artificial Carbon Sequestration:

Artificial methods involve human intervention to capture and store CO2, often from industrial processes or directly from the atmosphere.

a. Carbon Capture and Storage (CCS):

Carbon Capture: Techniques to capture CO2 emissions from industrial sources before they are released into the atmosphere.

Transport and Injection: Captured CO2 is transported via pipelines and injected into geological formations like depleted oil and gas reservoirs or saline aquifers for long-term storage.

b. Direct Air Capture (DAC):

Technologies: Machines or systems that actively capture CO2 directly from the ambient air using chemical, physical, or biological processes.

Storage and Utilization: Captured CO2 can be stored underground or used in various applications, such as carbon mineralization or industrial processes.

3. Biological Carbon Sequestration:

This type of sequestration involves enhancing the capacity of natural systems to sequester carbon through biological processes.

a. Enhanced Biological Sequestration:

Genetic Approaches: Modifying plants to increase their carbon sequestration capabilities through enhanced photosynthesis or growth rates.

Ecological Approaches: Implementing land management practices that promote carbon sequestration, such as agroforestry and cover cropping.

b. Carbon Farming:

Utilizing agricultural practices, like no-till farming and cover cropping, to increase carbon sequestration in soils.

These types of carbon sequestration techniques work in tandem to help balance the global carbon budget, reducing the overall concentration of CO_2 in the atmosphere and mitigating climate change. Each method has its own strengths, limitations, and suitability for different environments and applications. Integrating these approaches into comprehensive climate mitigation strategies is essential for combating the impacts of global warming.

Challenges and Considerations:

1. Cost and Energy Intensity:

Many carbon sequestration technologies are currently expensive to implement and operate. The energy required for processes like carbon capture and compression can be substantial, potentially offsetting the emissions reduction benefits.

2. Scale and Infrastructure:

Implementing large-scale carbon sequestration projects requires extensive infrastructure, including pipelines for transport, storage facilities, and monitoring systems. Developing this infrastructure can be time-consuming and costly.

3. Storage Integrity and Safety:

Ensuring the long-term stability and security of stored carbon is crucial. Leakage of stored carbon back into the atmosphere could negate the benefits of sequestration efforts. Rigorous monitoring and safeguards are necessary to prevent such incidents.

4. Technological Maturity and Innovation:

Some carbon capture and storage technologies are still in the early stages of development. Advancements in research and development are needed to improve the efficiency, scalability, and cost-effectiveness of these technologies.

5. Public Acceptance and Perception:

Public perception and acceptance of carbon sequestration technologies can be a significant hurdle. Concerns about safety, environmental impacts, and the long-term effectiveness of storage methods may impede public support.

6. Environmental Impacts:

Certain carbon sequestration methods, particularly geological storage, can have environmental impacts. Potential risks include induced seismic activity, groundwater contamination, and disruption of local ecosystems.

Future Prospects and Developments:

Future prospects and developments in carbon sequestration are crucial in the global effort to combat climate change. As technology advances and awareness of environmental challenges grows, several key areas are likely to see significant progress in carbon sequestration:

1. Technological Advancements in Carbon Capture:

Advancements in carbon capture technologies will play a pivotal role in increasing the efficiency and reducing the costs associated with capturing carbon dioxide from industrial processes and power plants. Research efforts are focused on developing more efficient sorbents, solvents, and membrane technologies for both pre- and post-combustion capture.

2. Enhanced Biological Sequestration:

Advances in genetic engineering and ecological approaches may lead to enhanced carbon sequestration in natural systems. This could involve the development of more efficient carbon-fixing plants or the optimization of microbial processes in soil to increase carbon storage.

3. Deep Geological Storage:

Research into safe and secure methods of storing captured carbon dioxide underground will continue. This includes the exploration of suitable geological formations, monitoring techniques, and strategies to prevent leakage.

4. Carbon Farming and Agroforestry:

The adoption of sustainable agricultural practices, such as agroforestry and carbon farming, has the potential to significantly sequester carbon in soil and vegetation. Advances in precision agriculture and the integration of climate-smart practices will further enhance these efforts.

5. International Collaboration and Agreements:

Strengthening international cooperation and agreements on carbon sequestration will be essential. Collaborative efforts can facilitate the exchange of knowledge, technology, and resources, enabling more widespread and effective implementation of sequestration strategies.

6. Innovation in Carbon Markets:

Advancements in carbon markets will provide economic incentives for businesses and industries to invest in carbon sequestration projects. This includes the development of robust measurement, reporting, and verification (MRV) systems to ensure the integrity of sequestration efforts.

Conclusion:

In conclusion, carbon sequestration stands as a critical pillar in the global fight against climate change. Its significance lies in its capacity to mitigate the impacts of rising atmospheric carbon dioxide levels, thereby helping to stabilize our planet's climate. Through natural processes like photosynthesis in forests and oceans, as well as through artificial means like Carbon Capture and Storage (CCS) and Direct Air Capture (DAC), we have a diverse toolkit to capture and store carbon. However, the journey towards effective carbon sequestration is not without its challenges. Technological refinement, cost reduction, and scaling up of these methods are necessary for widespread implementation. Additionally, careful consideration of environmental impacts and policy frameworks that incentivize sequestration efforts are vital components of any successful strategy. Looking ahead, the future of carbon sequestration holds great promise. Continued research and development efforts, coupled with international collaboration and innovative financial mechanisms, are poised to drive progress in this field. Enhanced biological sequestration, carbon utilization, and advancements in carbon capture technologies are among the areas that hold potential for substantial growth. As we move forward, it is imperative that we integrate carbon sequestration strategies into broader climate mitigation initiatives. This will not only facilitate the transition to a low-carbon economy but also contribute to the preservation of our planet's precious ecosystems. By harnessing the power of carbon sequestration, we are taking significant steps towards a more sustainable and resilient future for generations to come.

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Fuel cells: A promising future with ethanol and Non-Pt catalysts

Fuel cells are electrochemical devices that convert the chemical energy of a fuel and an oxidant into electricity. They are highly efficient and clean, producing only water and heat as byproducts. Fuel cells have the potential to revolutionize the way we generate and use energy, and they are already being used in a variety of applications, including portable electronics, transportation, and stationary power generation.

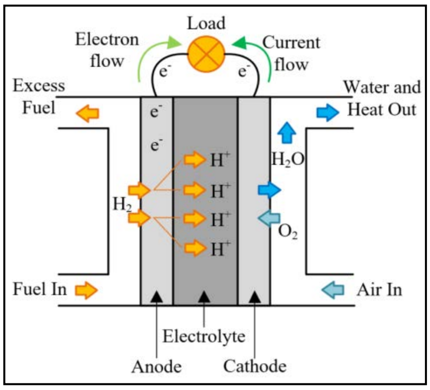

Figure 1-working of H2-O2 fuel cell

Hydrogen-oxygen fuel cells have been dominating the fuel cell market for many years due to their high efficiency and power density. They are also relatively mature technology, with a long history of development and commercialization.

- **High efficiency and power density**: H_2-O_2 fuel cells can convert chemical energy into electricity at an efficiency of up to 60%, and they have a high power density, meaning they can produce a lot of power in a small volume.
- **Mature technology**: H_2-O_2 fuel cells have been under development for many years, and they are now a relatively mature technology. This means that they are reliable and cost-effective to produce.
- **Wide range of applications**: H_2-O_2 fuel cells can be used in a wide range of applications, including portable electronics, transportation, and stationary power generation.

Despite the dominance of hydrogen-oxygen (H_2-O_2) fuel cells in the market, ethanol is emerging as a promising alternative fuel. Ethanol is a renewable fuel that is more abundant, less expensive, and easier to transport than hydrogen.

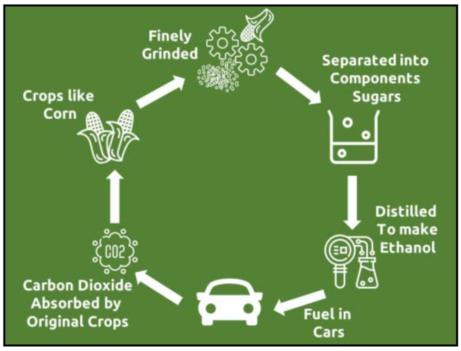

Figure 2- bio-ethanol production

Ethanol has several advantages over hydrogen as a fuel for fuel cells, including:

- **Abundant**: Ethanol is made from renewable sources like corn and sugarcane (bio-ethanol) Figure 2.
- **Cost-effective**: Ethanol is cheaper to produce than hydrogen.
- **Easy to transport**: Ethanol can be stored and transported like gasoline.
- **Safe**: Ethanol is less flammable and explosive than hydrogen.

Direct ethanol fuel cells (DEFCs) are a type of fuel cell that can use ethanol directly as a fuel, and they are rapidly advancing in terms of efficiency and performance.DEFCs could revolutionize the way we generate and use energy [6].

- Although methanol had relatively higher electrochemical activity but Methanol was tested as fuel (6.09 kWh/kg) whereas ethanol (8.01 kWh/kg) provided more energy density.
- Also it's worth noting ethanol have lower toxicity than methanol.

In recent discoveries, direct alcohol alkaline fuel cells (DAAFCs) or predominantly AEM based direct alcohol alkaline fuel cells **[DE(AEM)FC]** have emerged as a promising new type of fuel cell for a variety of applications. DAAFCs use ethanol [7] or other alcohols as a fuel and an alkaline electrolyte, which offers a number of advantages over traditional hydrogen fuel cells [Table 1] .DAAFCs are still under development, but they have the potential to be more efficient, cost-effective, and durable than hydrogen fuel cells. They are also more tolerant of impurities in the fuel, which makes them more suitable for use with real-world ethanol fuels.

Table 1- Parameters of electrochemical oxidation of some alcohols (under standard conditions)

Fuel	Anodic reaction	E^0 (V/SHE)	ΔG^0 (kJ/mol)	ΔH^0(kJ/mol)	W_e (kWh/kg)

Methanol	$CH_3OH + 6OH^- \rightarrow CO_2 + 5H_2O + 6e^-$	-0.81	-702.7	-726.7	6100
Ethanol	$CH_3CH_2OH + 12OH^- \rightarrow CO_2 + 9H_2O + 12e^-$	-0.77	-1326.7	-1367.9	8030
Iso-Propanol	$CH_3CHOHCH_3 + 2OH^- \rightarrow CH_3COCH_3 + 2H_2O + 2e^-$	-0.67	-1965.3	-2023.2	8600
Ethylene Glycol	$(CH_2OH)_2 + 14OH^- \rightarrow 2CO_3^{2-} + 10H_2O + 10e^-$	-0.72	-	-1273.3	5200
Glycerol	$HOCH_2CHOHCH_2OH + 20OH^- \rightarrow 3CO_3^{2-} + 14H_2O + 14e^-$	-0.69	-	-1723.1	5000

Now, Catalysts play a critical role in ethanol fuel cells, enabling the electrochemical conversion of ethanol into carbon dioxide, water, and electrons. The performance of an ethanol fuel cell is highly dependent on the activity and stability of the catalysts used.

Platinum (Pt) is the most commonly used catalyst for ethanol oxidation in fuel cells. However, Pt is expensive and can be poisoned by impurities in the fuel. To address these challenges, researchers are developing new catalysts based on other metals, such as palladium (Pd), Ruthenium (Ru), Tin (Sn) and nickel (Ni), as well as bimetallic and trimetallic alloys.Some of the promising catalysts for ethanol oxidation in fuel cells include:

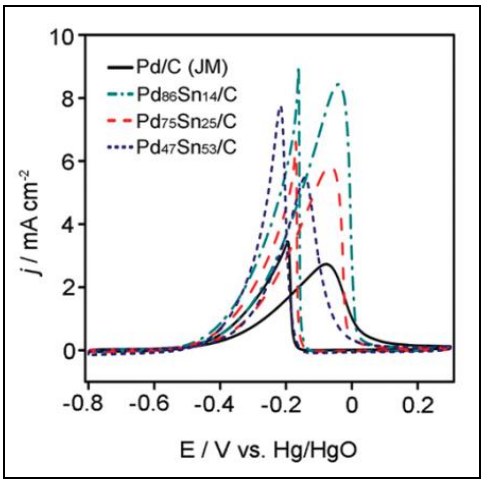

Figure 3- E/V vs. Hg/HgO of Pd-Sn alloys

- Pd-Sn alloys [1]

- Pd$_{86}$Sn$_{14}$/C showed much higher current densities than commercial Pd/C catalysts Figure 3- E/V vs. Hg/HgO of Pd-Sn alloys as in Figure 3.
- Pd$_{86}$Sn$_{14}$/C was more favorable in high ethanol concentration and/or high pH environment.
- DFT calculations confirmed that Pd$_{86}$Sn$_{14}$/C has lower reaction energies for the dehydrogenation of ethanol.

- Pd-Ru alloys [2]
  - The studies on effect of the Pd: Ru atomic ratio on the performance of PdRu/C catalysts for direct ethanol fuel cells showed bimetallic PdRu/C catalysts had higher activity and stability than commercial Pd/C catalysts as in Figure 4 .
  - The Pd$_3$Ru/C catalyst showed the highest power density, about 1.8 times higher than that of the Pd/C catalyst.

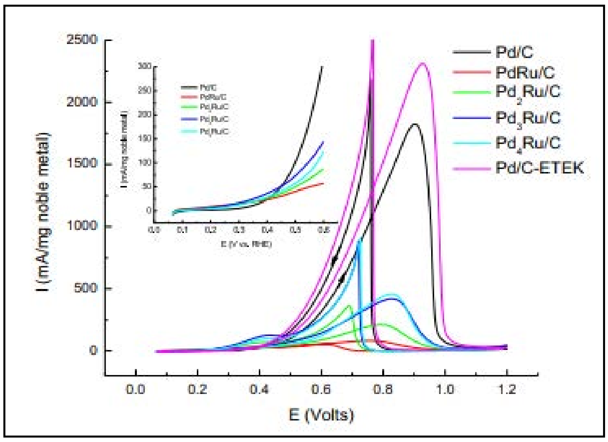

Figure 4- The CVs of Ru/C, PdRu/C, Pd/C and commercial Pd/C-ETEK electrocatalysts in an Ar-saturated 1 M NaOH +1 M ethanol solution. Scanning rate: 10 mV/s

- Pd–Ni–Sn alloys [3]

- A ternary catalyst with Pd, Ni, and Sn on MWCNTs exhibited the highest current density (291 mA/cm^2) for ethanol oxidation reaction (EOR), great catalyst stability, the highest electrochemical surface area (77.155 m^2 /g Pd), and excellent CO tolerance as in Figure 5 .
- The addition of Ni and Sn metals increased the catalytic activity and stability for EOR.
- The ternary catalyst on MWCNTs is a promising new catalyst for direct ethanol fuel cells with high activity, stability, and CO tolerance.

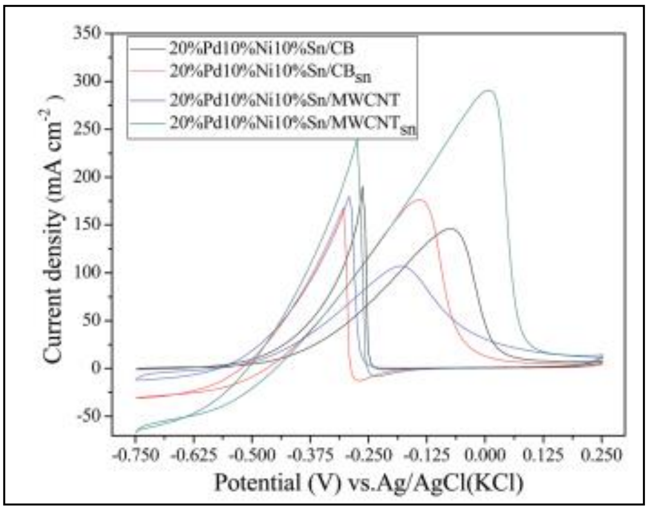

Figure 5- Voltammograms of 20%Pd10%Ni10%Sn deposited on different catalyst supports recorded in a mixture of 1 EOH and 1 M KOH at a scan rate of 50 mA/s

- Pd-Au-Ni alloys [4]
  - Ternary PdAuNi catalyst outperforms binary and monometallic catalysts in DEFCs. The PdAuNi catalyst exhibited a peak power density of 175% higher than the monometallic Pd catalyst (108 mW/cm^2), 108% higher than the PdNi catalyst (139 mW/cm^2), and 42% higher than the PdAu catalyst (127 mW/cm^2) as in Figure 6 .

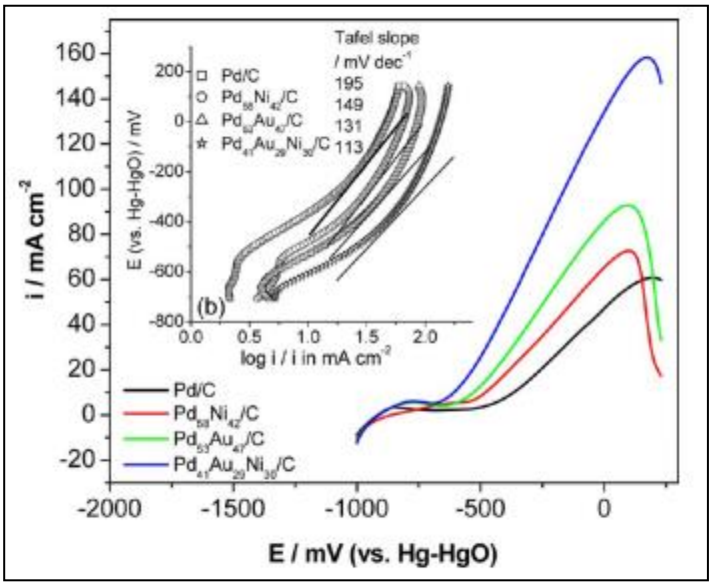

Figure 6- Potentiodynamic polarization plots for the electrochemical oxidation of 1.0 M ethanol in 0.5 M NaOH at a slow scan rate of 1 mV/s

- The PdAuNi catalyst is more stable and active than the other catalysts. This is likely due to the synergistic effects between the three metals.
- The PdAuNi catalyst produces more desirable reaction products. The PdAuNi catalyst produced more $CH_3CO_2^-$ (68%) and CO_3^{2-} (32%) than the other catalysts, which are more desirable reaction products in DEFCs.

These catalysts exhibit high activity and stability for ethanol oxidation, and they are also less expensive and more resistant to poisoning than Pt alone.

Ethanol and non-platinum catalysts have the potential to revolutionize the fuel cell industry. They offer a number of advantages, including reduced costs, improved durability, and reduced reliance on critical metals. With continued research and development, ethanol and non-platinum fuel cells could make fuel cells more affordable, durable, and sustainable, leading to a wider range of applications for this promising technology.

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Sustainable Approaches to Polymer Recycling and Upcycling

Abstract:

The escalating global concern over plastic waste pollution has prompted a critical revaluation of polymer lifecycle management. This research paper delves into sustainable methodologies for polymer recycling and upcycling, aiming to mitigate environmental impacts and promote resource conservation. The study comprehensively examines diverse polymer types, their inherent recycling challenges, and explores innovative techniques to address these hurdles. Mechanical recycling, a conventional process, is analysed alongside advanced chemical and biological recycling methods, shedding light on their potential to revolutionize the polymer waste landscape. Moreover, the paper emphasizes the transformative concept of upcycling, showcasing successful cases of reimagined polymer products and their economic and environmental merits. Drawing on case studies and industry examples, the research provides insight into the real-world application of sustainable practices, offering a glimpse into a future where discarded polymers find renewed purpose. The paper also considers policy and regulatory frameworks, discussing their role in fostering an environment conducive to sustainable polymer management. Ultimately, this comprehensive analysis underscores the urgency and feasibility of adopting sustainable approaches to polymer recycling and upcycling, envisioning a more resilient and ecologically responsible future.

Keywords: plastic waste pollution, recycling, upcycling, sustainable polymer management.

Introduction:

The surge in global concern regarding plastic waste pollution calls for a fundamental revaluation of polymer lifecycle management. With annual plastic production surpassing 360 million metric tons, the impacts of plastic consumption reverberate across ecosystems, posing a profound threat to biodiversity, human health, and environmental integrity. Urgency in addressing this crisis has catalysed a paradigm shift in how polymers are handled.

This paper delves into sustainable methodologies for polymer recycling and upcycling, illuminating a path toward a more environmentally harmonious future. The need to transcend conventional disposal methods arises from a convergence of environmental, economic, and societal imperatives. Chemical recycling emerges as a transformative force, promising to break down complex polymers into constituent monomers, enabling the creation of virgin-quality materials. Biological recycling offers an environmentally benign alternative for specific types of polymers. Upcycling, too, stands out as a beacon of resourcefulness, showcasing the potential within seemingly spent resources. This study aims to provide a comprehensive understanding of these sustainable approaches, offering insights that may galvanize a collective effort toward a more sustainable coexistence with the polymers that permeate our modern lives.

Beyond recycling, upcycling stands out as a beacon of ingenuity and resourcefulness in the sustainable management of polymers. By reimagining discarded materials, often deemed as waste, into high-value products, upcycling not only mitigates waste streams but also showcases the latent potential within seemingly spent resources. This transformative approach embodies the essence of sustainability, as it not only extends the lifespan of polymers but also minimizes the need for additional raw materials and energy-intensive production processes.

Types of Polymers and Their Recycling Challenges:

1. **Polyethylene (PE):**
   - Description: PE is commonly used in various forms, including low-density (LDPE) and high-density (HDPE) plastics, found in items like plastic bags and bottles.
   - Recycling Challenge: Sorting different grades of PE can be challenging due to their similar appearances. Additionally, removing contaminants like dirt, labels,

and other materials from post-consumer plastics requires specialized equipment and processes. The presence of different types of PE in the recycling stream can affect the quality of the recycled material.

2. **Polypropylene (PP):**
   - Description: PP is a versatile plastic used in a wide range of applications due to its high melting point and chemical resistance, including packaging, automotive parts, and household items.
   - Recycling Challenge: Contamination from food residues and other materials can be problematic, requiring thorough cleaning before recycling. Achieving high levels of purity is crucial for recycling efficiency. The variety of products made from PP, each with different additives, can complicate the recycling process.

3. **Polyvinyl Chloride (PVC):**
   - Description: PVC is a durable plastic known for its chemical resistance, commonly used in pipes, cables, and vinyl products in construction and automotive industries.
   - Recycling Challenge: PVC has a complex chemical structure, making it challenging to recycle. Additionally, the presence of additives like plasticizers and stabilizers can complicate the recycling process. Contamination with non-PVC materials can affect the quality of recycled PVC.

4. **Polystyrene (PS):**
   - Description: PS is used in various forms, including solid and foam, and is known for its lightweight and insulating properties, found in packaging, disposable utensils, and insulation materials.
   - Recycling Challenge: Expanded polystyrene (EPS) foam, commonly used in packaging, is challenging to recycle due to its low density and potential for

contamination. The lightweight nature of EPS also makes it less economically viable to transport for recycling.

5. **Polyethylene Terephthalate (PET):**
    - Description: PET is a widely used plastic known for its clarity, strength, and recyclability, commonly found in beverage bottles and food containers.
    - Recycling Challenge: Mechanical recycling of PET faces challenges with decontamination. Removing labels, adhesives, and other non-PET components is labour-intensive and affects recycling efficiency. The presence of different types of PET, such as coloured or opaque bottles, can complicate the recycling process.

6. **Nylon (PA):**
    - Description: Nylon is a strong and durable synthetic material used in textiles, automotive components, and industrial applications.
    - Recycling Challenge: The high melting point of nylon requires specialized equipment for recycling. Additionally, contamination from other materials can impact the quality of recycled nylon. Different types of nylon (e.g., nylon 6, nylon 66) have distinct properties and recycling processes.

Polymer Recycling Methods:

Polymer recycling methods encompass a range of techniques aimed at reclaiming and repurposing polymers from waste materials. These methods play a crucial role in mitigating plastic waste and reducing the environmental impact of polymer production. Here are the primary polymer recycling methods:

1. **Mechanical Recycling:**
    - Description: This is the most common method, involving the physical processing of plastics to create new products.

- Process: It includes steps like sorting, cleaning, shredding, melting, and forming. The resulting material can be used to manufacture a variety of products, including containers, fibers, and packaging materials.
- Advantages: Mechanical recycling is relatively simple, cost-effective, and energy-efficient compared to other methods. It also retains the inherent properties of the original polymer.
- Challenges: It is limited by the need for clean and sorted input materials. Moreover, multiple recycling cycles can lead to a decrease in material quality and performance.

2. **Chemical Recycling (Feedstock Recycling):**
   - Description: Chemical recycling involves the breakdown of polymers into their constituent monomers or other valuable chemicals, which can then be used to produce new plastics or other materials.
   - Process: Techniques such as pyrolysis, depolymerization, and solvolysis are employed to break down complex polymers into simpler chemical compounds. These can be used as feedstock for new polymer synthesis.
   - Advantages: Chemical recycling can handle a wider range of plastics, including mixed or contaminated materials. It also allows for the recovery of high-quality monomers.
   - Challenges: It often requires significant energy inputs and may generate by-products. Moreover, scaling up chemical recycling processes to meet industrial demands can be complex.

3. **Biological Recycling (Biodegradation and Composting):**
   - Description: This method relies on natural biological processes to break down organic polymers into simpler, environmentally benign substances.

- Process: Microorganisms like bacteria and fungi play a vital role in the degradation process. Composting involves providing the right conditions (e.g., moisture, temperature) for organic polymers to decompose.
- Advantages: Biological recycling is particularly suited for biodegradable polymers like PLA (polylactic acid) and certain natural polymers. It offers a sustainable approach to managing certain types of plastic waste.
- Challenges: It requires controlled environments to ensure efficient degradation. Additionally, not all polymers are biodegradable, limiting the applicability of this method.

Upcycling of Polymers:

Upcycling is a process that breathes new life into discarded polymer materials. It involves creatively reimagining and repurposing these materials to create products of higher value. This sustainable approach starts with sorting and cleaning the polymers, followed by innovative processing and modification techniques. The result is a transformed material with enhanced properties and potential applications. Upcycling reduces environmental impact, conserves resources, and sparks innovation. It is a key step toward a more circular and responsible use of plastic materials.

The process involves:

- Sorting and Cleaning: Discarded polymer materials are sorted and cleaned to remove contaminants and prepare them for transformation.
- Creative Transformation: Engineers and designers creatively reimagine these materials, exploring innovative uses and potential applications.
- Processing and Modification: The selected polymers are processed using techniques like extrusion or molding, with potential modifications for improved performance or aesthetics.

- Value Addition: Additional elements like reinforcing fibers or coatings may be incorporated to enhance the material's properties.
- Quality Assurance: Stringent checks ensure that the upcycled products meet specified standards for safety, durability, and functionality.
- Market Integration: The upcycled products find their way into various markets, from consumer goods to architectural applications.

Case Studies:

Case studies on sustainable approaches to polymer recycling and upcycling:

1. **Adidas and Ocean Plastic Parley Collaboration:**
    - Background: Adidas partnered with Parley for the Oceans to transform marine plastic waste into sportswear.
    - Approach: Parley collected coastal plastic, processed it into technical fibres, and Adidas incorporated it into their products.
    - Impact: Millions of pairs of Adidas shoes containing recycled ocean plastic have been sold, showcasing the viability of using recycled materials in high-performance sportswear.

2. **The Plastic Bank - Social Plastic Initiative:**
    - Background: The Plastic Bank combats ocean plastic pollution while addressing poverty by establishing recycling centres.
    - Approach: Collected plastics are transformed into Social Plastic, a certified recycled material used in various products.
    - Impact: The initiative removes plastic waste from the environment, provides income to local communities, and creates a market for recycled plastics.

3. **Terracycle and Loop's Circular Shopping System:**
    - Background: Loop, in partnership with Terracycle, introduced a circular shopping system to reduce packaging waste.
    - Approach: Loop offers reusable packaging for various products, which is collected, cleaned, and reused.
    - Impact: The initiative promotes a more sustainable shopping experience by minimizing single-use packaging and encouraging a circular economy approach.

Environmental and Economic Impacts:

Environmental Impacts:

1. Resource Conservation: Recycling and upcycling polymers conserves natural resources by reducing the need for new raw materials. This helps preserve fossil fuels and minerals used in polymer production, contributing to sustainable resource management.

2. Waste Diversion: Sustainable polymer practices divert plastic waste from landfills and incineration, minimizing environmental harm and alleviating the strain on waste management systems. This reduces the pollution and emissions associated with traditional disposal methods.

3. Ocean Pollution Mitigation: Initiatives targeting ocean plastic, like Adidas' collaboration with Parley, prevent marine pollution. By repurposing plastic waste found in coastal areas, these efforts protect marine ecosystems and mitigate the impact of plastic on ocean health.

Economic Impacts:

1. Job Creation: The recycling and upcycling industry creates employment opportunities in areas such as collection, sorting, processing, and manufacturing of recycled materials. This contributes to local economic development and supports livelihoods.

2. Cost Savings for Businesses: Businesses that utilize recycled polymers can experience cost savings, as recycled materials are often more cost-effective than virgin plastics. This reduces expenses related to raw material procurement.

3. Market Growth and Innovation: Sustainable polymer practices create new markets for recycled products, driving innovation and entrepreneurship. This leads to the development of novel products and technologies in the recycling and upcycling sector.

Challenges and Future Prospects:

Challenges:

1. Contamination and Sorting: The presence of non-polymeric materials, labels, and adhesives in plastic waste stream complicates the sorting process. Effective separation is essential for producing high-quality recycled materials.

2. Polymer Diversity: The wide variety of polymers with different chemical compositions and properties makes it challenging to develop universal recycling techniques. Each type of polymer requires specialized processes.

3. Technological Constraints: Some polymers, especially complex composites and multi-layered materials, pose difficulties for traditional recycling methods. Advancements in technology are needed to overcome these barriers.

Future Prospects:

1. Material Innovation and Design Optimization: Developing polymers that are inherently more recyclable and designing products with end-of-life considerations in mind will streamline the recycling process and reduce waste.

2. Consumer Education and Participation: Educating consumers about responsible plastic use and disposal will drive demand for sustainable products and encourage recycling behaviour, creating a more eco-conscious market.

Conclusion

The sustainable approaches to polymer recycling and upcycling represent a pivotal shift in our relationship with plastics. Through innovative processes, these methods breathe new life into discarded materials, reducing waste and lessening the environmental impact of polymer production. By prioritizing resource conservation, waste diversion, and pollution mitigation, these practices align with a broader commitment to a greener future. While challenges persist, including contamination, diverse polymer types, and technological limitations, ongoing research and collaborative efforts are paving the way for more efficient and scalable solutions. The integration of advanced recycling technologies, adoption of circular economy principles, and material innovation are poised to revolutionize the way we manage plastics. As consumers become more informed and engaged, and as industries and policymakers forge alliances, the prospects for sustainable polymer practices are bright. With concerted efforts, we have the potential to usher in a new era of responsible plastic utilization, where materials are reused, repurposed, and recycled at their highest value. Through these sustainable approaches, we not only address the immediate issue of plastic waste but also contribute to a more harmonious and balanced coexistence with our environment.

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POLYMERS IN NANOMEDICINE

Polymers are an indispensable part of our everyday lives. Polymeric nanoparticle is one of the most studied organic strategies for nanomedicine. These are generally used as a nanoparticle career to reduce the toxicity and increase cellular uptake. Polymers have been studied extensively, based on their chemical and physical properties in bioscience applications. It has some way or functional component of drug delivery system in nanomedicine. We treat polymer as if we could reproduce the synthesis in a way we can do.

- **Polymer**

A polymer is a large molecule or macromolecule formed for lots of monomer repeating units joined together.

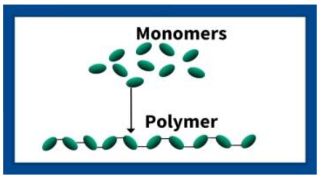

Fig: Monomers forming polymer

- **Nanomedicine**

Nanomedicine is medical application of Nanotechnology. Nanomedicine is used in nano-sized tools for the diagnosis and prevention and treatment of disease and to gain increased and understanding of the complex underlying patho-physiology of disease. The ultimate goal is to improve quality of life .It is the field of study of device and mechanism on nanoscale level 1-100 nm.

How polymer is used in nanomedicine?

Polymer plays an important role in the medical application of nanotechnology because it has various benefits like flexibility, low cost, diverse functionalities, nanometer-sized, processability and microphase separation.

Advantages in the use of polymer:

- Increased functionality
- Design flexibility

- Improved process ability
- Biocompatibility.

Factors affecting polymers which are used in nanomedicine

There are some systems by which the polymers are used to work for nanomedicine.

1. pH-Sensitive Systems
2. Thermoresponsive Systems
3. Enzyme-Responsive Systems
4. ROS-Sensitive Systems (Reactive oxygen species)
5. Glutathione/Reductive Environment-Responsive Systems
6. ATP-Responsive Systems
7. Combination of Stimuli

TYPES OF POLYMER THAT USED IN NANOMEDICINE

- <u>SMART POLYMER</u>

Smart polymers are those, which are man-made with specific polymeric properties. Scientists have been attracted to the property for using smart polymers for the delivery of drugs. These are site specific, so they are preferred for drug delivery. They are known as “Intelligent Delivery Systems” because of its ability to deliver at accurate time and specific sites. Smart polymers are generally hindered by certain physical, chemical, and biological stimuli.

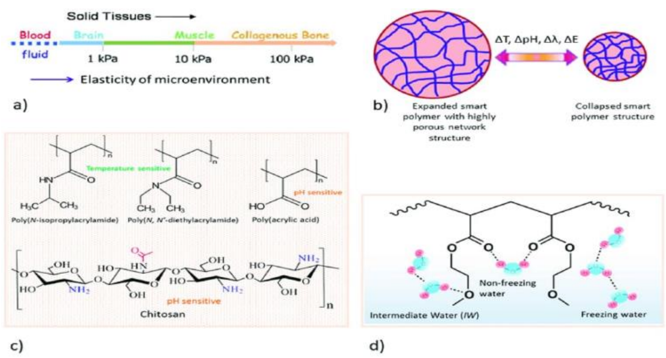

Fig: Smart polymer structure

- <u>DENDRITIC POLYMER</u>

Dendrimers are generally highly ordered, branched polymeric molecules. Dendrimers for drug delivery are employed by two terms: (i) formulation and (ii) nanoconstruct. In the formulation approach, drugs are entrapped physically in a dendrimer using non-covalent interactions, whereas drugs are covalently coupled with dendrimers in the nanoconstruct approach. Typically, dendrimers are mainly symmetric about the core, and adopt a spherical three-dimensional morphology.

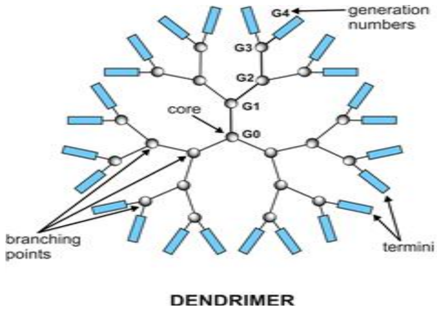

Fig: Dendritic polymer structure

- <u>MICELLES POLYMER</u>

Polymeric micelles are nanoscopic core or shell structures that is formed by amphiphilic block copolymers. Inherent and modifiable properties of polymeric micelles make them particularly well suited for the drug delivery purposes**.**

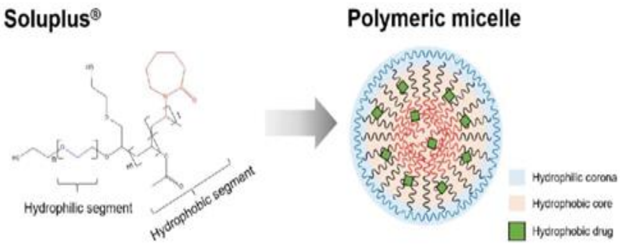

Fig: Micelles polymer structure

Uses: Polymeric nanomaterial-based therapeutics plays a major role in the field of medicine in treatment areas such as

- Drug delivery
- Tissue engineering
- Cancer
- Diabetes
- Neurodegenerative diseases
- Bacterial infections

- Inflammatory diseases
- Atherosclerosis
- Rheumatoid arthritis.

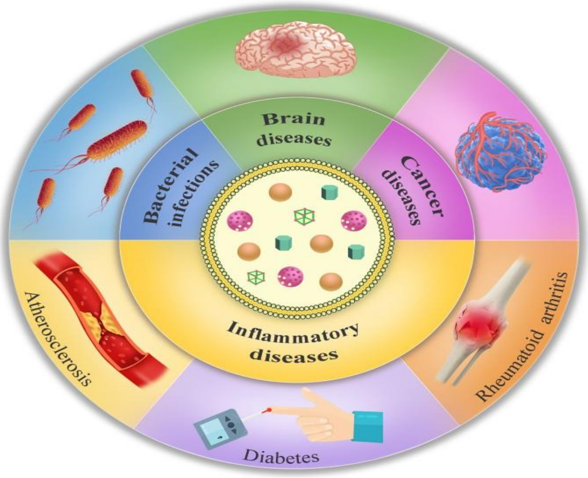

Fig: Polymer's role in several treatments

Further perspective

We have explored the current research application of polymer in nanomedicine. Nanomedicine is an interdisciplinary field that requires the close collaboration of physicist, chemists, biologist, and physician. Recent advances in polymer design mechanism applications are received here. So, to progress further in this area of precision medicine, it signifies a patient-centric approach. Polymer in nanomedicine research is the momentum of transitional research in the future perspective.

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STUDY OF FEASIBILITY OF NON- NEWTONIAN FLUID IN MILITARY VESTS/ARMOURS - A REVIEW

Abstract

Non-Newtonian fluids are fluids whose viscosity, or resistance to flow, changes with the applied shear rate or shear stress. These fluids have the ability to significantly alter their viscosity in response to external forces, making them useful in a variety of applications. One potential application of non-Newtonian fluids in the military is in the development of protective vests. These vests are designed to absorb and disperse the impact of bullets and other projectiles, protecting the wearer from injury. Non-Newtonian fluids, such as shear thickening fluids (STFs), can be incorporated into the vest material to improve its protective capabilities. STFs are a type of non-Newtonian fluid that become more viscous under shear stress, such as that caused by a bullet impact. When a bullet strikes an STF-based vest, the fluid's viscosity increases, causing it to absorb and disperse the impact energy more effectively. This can significantly reduce the amount of force transmitted to the wearer, potentially reducing the severity of injuries sustained in combat.In addition to their protective capabilities, non-Newtonian fluids have the advantage of being lightweight and flexible, making them well-suited for use in military vests. They can also be easily integrated into existing vest designs, allowing for the development of improved protective equipment without the need for significant redesign. Overall, the use of non-Newtonian fluids in military vests has the potential to provide improved protection for soldiers in combat situations. This review paper shall explore the practicality and feasibility of non newtonian fluid in military vests as liquid body armours from various literatures available in peer reviewed journals.

INTRODUCTION

In modern day scenario with rapid development in weapons , developement of military vests and armours is inevitable. Armours needs to get more and more effective and in this situation STF Liquid Armour comes into play. STF Liquid Armour is alternative type of armour that can be used as it has superior efficiency when compared to the conventional kevlar armours. STF Armours incorporates non newtonian fluids which during impact with high velocity projectiles thickens and hardens resulting in decrease in damage for the wearer. This STF Liquid Armour is a relatively new concept and research is going on. This paper will explore the feasibility of STF Liquid Armour as a military armour from various literature works that are available.

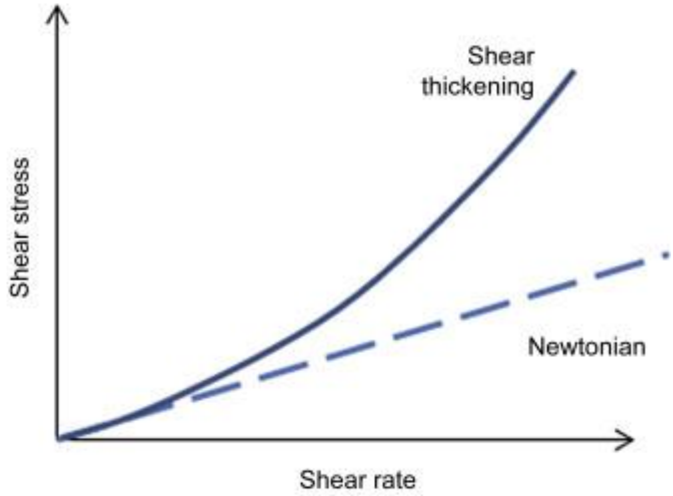
Non Newtonian Fluids

Non Newtonian fluid is a fluid that behaves in a way that contradicts Newton's original theories. Newton's law of viscosity defines the relationship between the shear stress and shear rate of a fluid subjected to a mechanical stress. The ratio of shear stress to shear rate is a constant, for a given temperature and pressure, and is defined as the viscosity or coefficient of viscosity.

There are four types of Non-Newtonian fluids, and they are:

- Dilatant: The viscosity of these fluids increases when shear stress is applied. Quicksand, cornflour with water, and putty are examples of dilatant fluids.
- Pseudoplastic: The viscosity of these fluids decreases when shear stress is applied. These fluids are the opposite of dilatant fluids. Ketchup is an example of pseudoplastic.
- Rheopectic: The viscosity of these fluids increases when shear stress is applied along with time. They are similar to dilatant fluids, however, these fluids are time-dependent. Cream and gypsum paste are examples of rheopectic fluids.
- Thixotropic: The viscosity of these fluids decreases when shear stress is applied along with time. Cosmetics and paint are examples of thixotropic fluids.

In application on military vests our area of interest will be specifically on Dilatant fluids which is also called shear thickening fluid (STF).



Pic: Rate of change of shear stress with shear rate

Military Body Armours

Modern body armours are classified into two categories

SOFT ARMOURS

This type of armor is made from flexible materials like Kevlar or Spectra and is designed to protect against small caliber handgun rounds. It is often worn by law enforcement officers and is relatively lightweight and comfortable to wear.

HARD ARMORS

This type of armor is made from hard materials like ceramic, steel, or polyethylene and is designed to protect against high caliber rifle rounds. It is often worn by military personnel and is much heavier and less flexible than soft body armor. Hard plated armours uses military grade Kevlars like KM2 or KM129

In the above two mentioned types of modern day armour there is a problem of low efficiency and low flexibility. Therefore to eliminate these problems a new type of armour named liquid body armours can be used which is observed to more flexible and more efficient.

Liquid vest

Liquid armor is a type of body armor that is made from a liquid material that hardens when subjected to an external force. It is designed to provide protection against high velocity bullets and other types of impact. Shear Thickening fluids are used which can be incorporated with with Kevlar . When STF is in liquid form, the weak molecular interactions between the silica particles permit them to move around freely in the liquid polymer without binding to one another. However, a ballistic or penetrative strike to the material (because the energy of impact is much greater than the energy between the metal particles) forces the particles to temporarily assemble into hydroclusters – long irregularly shaped chains of molecules. The hydroclusters subsequently overlap to form a mesh-like structure, which dramatically increases the viscosity of the liquid . As soon as the energy from the mechanical stressor disappears, this process reverses itself, and the substance returns to a liquid state. In addition to their protective capabilities, non-Newtonian fluids have the advantage of being lightweight and flexible, making them well-suited for use in military vests. They can also be easily integrated into existing vest designs, allowing for the development of improved protective equipment without the need for significant redesign.

Types Of Liquid Armours

One type of liquid armor is called Shear Thickening Fluid (STF) armor, which is made from a mixture of particles suspended in a liquid medium. When the armor is struck, the particles in the fluid become more rigid, increasing the armor's resistance to penetration. STF armor is lightweight and flexible, making it comfortable to wear and easy to move in. It can also be molded into various shapes and sizes, making it suitable for use in a wide range of applications. The STFs used can be Oobleck which is mixture of cornflour and water in 2:1 ratio or Polyethylene Glycol (PEG) with silicon dioxide ($SiO2$) .

Another type of liquid armor is called Electro-Rheological (ER) armor, which is made from a suspension of particles in a liquid that changes viscosity when an electric current is applied. When an electric current is applied, the particles in the liquid become more rigid, increasing the armor's resistance to penetration. ER armor is more complex to manufacture than STF armor, but it has the advantage of being able to be activated and deactivated as needed, making it more versatile.

Both STF and ER liquid armor have the potential to provide a high level of protection against bullets and other impacts, and they may be used in a variety of applications, including military and law enforcement, as well as in sporting goods and other protective gear.

Tests

Various tests have been preformed or can be performed to determine various parameters like efficiency and flexibility.

Impact Test

In this test three sample were taken .sample 1 contained only kevlar tile, sample 2 kevlar sandwiched between Oobleck and sample 3 contains kevlar sandwiched between PEG and SiO2. The STF was taken into a cylindrical rubber container and placed between layers of kevlar.Two series of tests were carried out. First was with glasses and second without glasses. Glass tiles of varying thickness were placed behind test tiles and tested. Glasses were put in a sack individually and was inserted in the slot of the frame along with the test tiles. Shooting was done from a distance of 50 m. The same test procedure was carried out for all the test samples. The second series of tests were done by placing the test samples alone in the slot without the glasses. These samples were made to rest directly on the back plate of the frame and were shot. There were dents produced on the back plate of the frame when shots were made in all the tests. These dents were of different sizes corresponding to different test samples and method. The dimensions were analyzed to find out the effectiveness of using Non-Newtonian fluids and the data were noted down in form of tables and graphs.

TABLE 1 Results of test keeping glass behind each sample

SAMPLE NO.	SAMPLE DESCRIPTION	GLASS THCKNESS (mm)	DEPTH (mm)
1	Kevlar	4	2
1	Kevlar	6	1.9
2	Kevlar with Oobleck	4	-
2	Kevlar with Oobleck	6	-
3	Kevlar with PEG & SiO_2	4	0.8
3	Kevlar with PEG & SiO_2	6	0.38

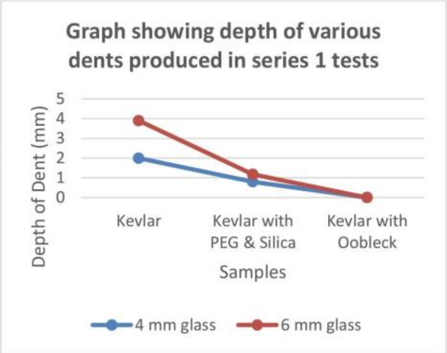
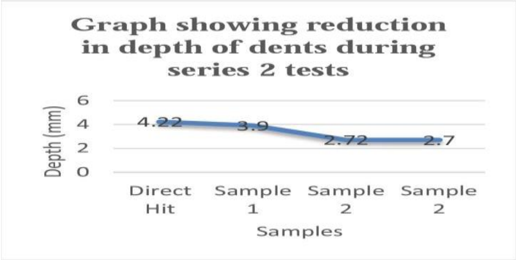


TABLE 2 Results for testing without glasses

Sample	Depth (mm)
None (Direct Hit)	4.22
Kevlar-1	3.9
Kevlar with Oobleck-2	2.72
Kevlar with Oobleck-2	2.7



Ballistic Test

Ballistics testing is an essential part of the production of a variety of products. Ballistics is defined as the study and science of projectiles and firearms.

Ballistics testing is **a standards-based process where products are tested to determine if they meet protection, safety and performance criteria**.

Most ballistics testing helps commercial research and development programs as well as law enforcement and military applications. the most common applications for testing armour form of testing are:

Personal protective equipment — Bulletproof vests and other equipment worn by law enforcement and military personnel.

Vehicle and structural armor — Bulletproof vehicles and glass both require sufficient ballistics testing.

Firearms and munitions — Both need to be tested before use to ensure that they are safe.

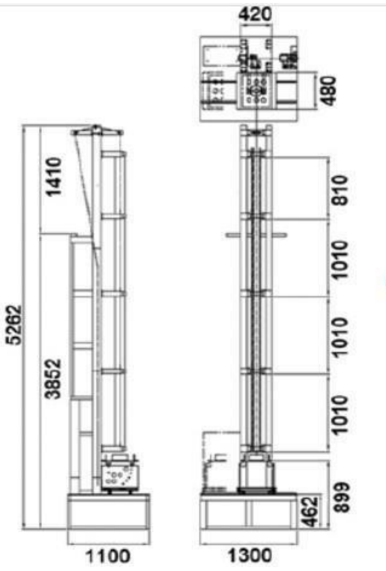
Types of Ballistic Tests

Ballistic testing can vary dramatically from one test to the next, depending on the needs of the individual contract.

- Threat tests for spheres, cubes, RCCs, FSPs, etc.
- Low velocity and fragmentation tests
- Small- and medium-caliber threats (up to 30mm)
- Spiked- and edged-weapon threats for stab-proof vests

Tower Drop Stab Test

In the tower drop stab test, two tests are performed on neat Kevlar and STF-Kevlar samples. The test proved that the STF-Kevlar was able to show a result that was slightly better than the neat Kevlar. This backing consists of four layers of 5.8-mm-thick neoprene sponge, followed by one layer of 31-mm-thick polyethylene foam, backed by two 6.4-mm-thick layers of rubber (all backing materials from PCF Foam Corp., Cincinnati, OH). Synthetic polymer based Polyart™ witness papers (Arjobex Corp., Charlotte, NC) were placed between the target and foam backing, and behind each layer of neoprene sponge.

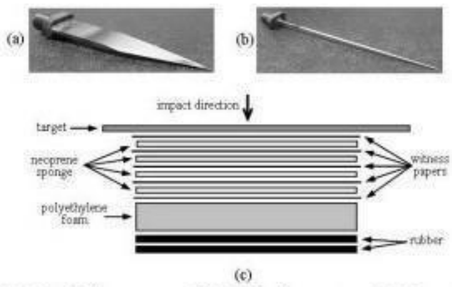


Tower Drop Test Diagram

Steps to perform the experiment

- To perform a stab test, the impactor is mounted to the crosshead, which is then loaded with weights to a specific mass. The crosshead is dropped from a fixed height to impact the target. The velocity of the crosshead at impact is measured using fixed flags and sensors attached to the frame. Impact loads are measured using a load cell mounted to the impactor.
- The stab testing procedure used in this study differs from the NIJ study in two important ways. First, the NIJ standard uses a two-mass, damped impactor. This damping more closely represents realistic stabbing dynamics than our rigidly-mounted impactor.
- Therefore, our energy values cannot be directly compared to NIJ-based energy values, but we expect superior performance for our materials in the NIJ standard tests of similar energy. Secondly, our configuration uses multiple witness paper layers to measure depth of penetration. The NIJ standard calls for inferring depth of penetration based on measuring the final location of the blade in the backing material.

- Note that the allowable depth of penetration for the NIJ standard, for which injury would be unlikely, is 7 mm. Since the thin foam witness layers are 5.8 mm thick, and the first layer of witness paper is on top of the foam backing, tests in which only 1 or 2 witness layers are penetrated correspond to adequate protection.



(a) Knife impactor. (b) Spike impactor. (c) Foam backing.

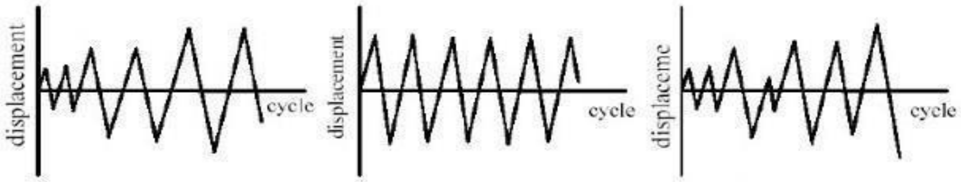
Conditions for drop tower stab testing.

Drop mass (kg)		Drop height (m)	Theoretical impact velocity (m/s)	Theoretical impact energy (J)	
Spike	Knife			Spike	Knife
2.33	2.34	0.1	1.40	2.29	2.29
2.74	2.75	0.1	1.40	2.68	2.69
3.14	3.15	0.1	1.40	3.08	3.09
3.60	3.61	0.1	1.40	3.53	3.54
4.01	4.01	0.1	1.40	3.93	3.94
4.67	4.68	0.1	1.40	4.58	4.59
2.33	2.34	0.25	2.21	5.72	5.74
2.33	2.34	0.5	3.13	11.43	11.47
2.33	2.34	0.75	3.84	17.15	17.21

Quasi-static test

A quasi-static test is described as **energy absorption capability of the composite when they are crushed under axial loads**. The quasi-static tests are performed using a hydraulic press where the specimen is crushed at a very low crosshead speed between two parallel steel platens .The quasi-static cyclic tests can be used to conduct both basic and proof tests. In quasi-static tests, loads and/ or displacements are applied at slow rates .The slow loading rate during the test has the advantage of providing an insight regarding the behavior of a structure/structural member in the postyielding regime. However, the associated disadvantage is that the effects of acceleration-dependent inertial forces and velocity-dependent damping forces are eliminated, which can be significant for some structural types.

Similarly, by using the jacks and actuators the external actions are 'lumped' on the structure. These actions try to simulate the inertial forces that are developed due to mass on the structure.



(a) Variable Amplitude (b) Constant Amplitude (c) Mixed Amplitudes

Flexibility test

- a mechanical flexibility test is developed which can be used to assess multi layer body armour systems. This is compared with a subjective manual test, and then with the results of wearer trials conducted using the recently approved ISO body armour standard ISO 14876-1 (2002). A series of trials was conducted on six different ballistic and/or stab resistant body armour types with a variety of protection levels and constructions.
- A series of trials was conducted on six different ballistic and/or stab resistant body armour types with a variety of protection levels and constructions. These were tested using the mechanical test system in which the armour was forced through a 200 mm hole by a 100 mm hemispherical plunger.
- The results of this test were then compared to a second set of trials in which flexibility of the same armour was assessed by manual handling and flexing of the armour. Finally an ergonomic wearer trial was conducted with four armours according to ISO 14876-1 (2002) each armour being assessed by four volunteers and the results compared to flexibility data collected in the first two trials.
- These results in turn showed reasonable but not exact correlation with the wearer trials. The ISO wearer trials addressed other factors such as overall comfort and fit of the systems and so the results were not purely a function of flexibility.

Conclusion

From this paper we have discussed about the application of non newtonian fluids in liquid armours with various test to observe the superiority over conventional armour. We have come across many graphs and data that points toward to feasibility of liquid body armour as an alternative and more efficient armour as it is evident that Liquid Body armour made with STFs are far more flexible and efficiently distributed the high impact of high velocity projectiles thereby significantly reducing the damage. Although many datas were incomplete so it is insufficient for drawing a concrete conclusion but a constant trend can be observed that indicates the far more efficiency and flexibility of liquid armour over solid or soft armours. A lot can be said STF liquid armour as an alternative armour.It has it's own challenges but one thing is certain that STF liquid armour is feasible armour and can be used over conventional armours.we just need more data and further studies have to be done as this concept is in it's theoretical stage. Thus from this paper we can conclude that STFs Liquid armour is indeed viable as an alternative body armour.

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FUTURE PROSPECT OF AI IN CHEMICAL ENGINEERING

The field of Chemical Engineering is on the brink of a transformative revolution, with Artificial Intelligence (AI) poised to play a pivotal role. This technical essay delves into the future prospects and scopes of AI in Chemical Engineering, encompassing applications in process design, optimization, safety, materials discovery, and environmental sustainability. It also explores the challenges and ethical considerations that must be addressed as AI becomes increasingly integrated into this domain.Chemical Engineering is a multidisciplinary field at the intersection of chemistry, physics, and engineering, with applications in diverse industries such as petrochemicals, pharmaceuticals, materials science, and environmental management. The advent of AI technologies promises to reshape the landscape of Chemical Engineering by offering innovative solutions to complex problems.

AI has already made significant strides in process optimization and control within chemical engineering. Machine learning algorithms, neural networks, and other AI techniques are being employed to analyze vast amounts of data generated in chemical processes. These algorithms can identify patterns, predict outcomes, and optimize various parameters in real-time. This application leads to increased efficiency, reduced waste, and improved yields in manufacturing processes.The future of AI in chemical engineering process optimization lies in the development of even more sophisticated predictive models. These models will not only focus on real-time optimization but will also predict and adapt to changes and disturbances in the process. By integrating AI with process control systems, these predictive models will enable adaptive control strategies that continuously optimize production, responding to fluctuations in raw material quality, energy availability, or other variables.The future prospect of autonomous operations in chemical engineering is imminent. AI-driven systems will move towards autonomous control, where entire production units or even plants can run without continuous human intervention. These systems will self-optimize, self-diagnose, and selfcorrect, making decisions in line with predefined safety and production parameters. This not only enhances efficiency but also significantly reduces the risk of human errors.The integration of AI with the Internet of Things (IoT) and Big Data will be a game-changer in process optimization and control. IoT devices, coupled with AI, will enable a higher degree of connectivity and data acquisition from various points in a production facility. This massive influx of data will be processed using AI to extract valuable insights, providing a more comprehensive understanding of the entire manufacturing process.One of the key future developments will involve AI systems making decisions in real-time. These systems will analyze data streams from sensors and various process control points to make split-second decisions, ensuring optimal process conditions are maintained. This capability will be instrumental in preventing off-spec production, reducing energy consumption, and ensuring consistent product quality.Despite the promising future, challenges persist. An ongoing challenge is the need for high-quality and reliable data for AI models. Ensuring data integrity, accuracy, and accessibility is essential for effective AI-driven process optimization. Another challenge is the interpretability of AI models, where understanding the rationale behind AI-generated decisions remains crucial.

The future developments in AI for process optimization and control will focus on Explainable AI (XAI) to enhance the interpretability of models. This will enable engineers to understand and trust AI recommendations, leading to better integration of AI systems into existing workflows.

AI algorithms, particularly machine learning and optimization techniques, can revolutionize the way chemical processes are designed and improved. AI models can analyze vast datasets to optimize parameters, reduce energy consumption, minimize waste, and enhance product quality. These advancements can significantly reduce costs and increase overall efficiency.AI systems can monitor chemical processes in real-time and predict potential safety hazards. Through data analysis and predictive modeling, AI can identify abnormal patterns, triggering immediate responses to mitigate risks. This proactive approach enhances the safety of operations and protects both workers and the environment.The discovery of new materials is a critical aspect of Chemical Engineering. AI-driven computational tools enable researchers to explore and predict the properties of materials more efficiently. Machine learning algorithms can analyze large databases of chemical information to guide the design of novel materials with tailored properties, fostering innovation across industries.The integration of AI into Chemical Engineering can significantly contribute to environmental sustainability. AI-powered process optimization reduces energy consumption and waste generation, lowering the carbon footprint of chemical processes. Furthermore, AI aids in designing eco-friendly chemicals and materials, promoting green chemistry principles.The widespread adoption of AI in Chemical Engineering is not without its challenges. Data quality and availability remain a concern, as well as the interpret ability of AI models. The transition to AI-driven processes may require substantial capital investments in technology and workforce training. Ensuring data security and preventing counterattacks is also of paramount importance.Ethical concerns surround the use of AI in Chemical Engineering, particularly in terms of safety and environmental impact. Engineers must prioritize human safety and environmental stewardship over cost-saving measures. Transparent AI decision-making processes and strict adherence to ethical guidelines are essential to maintain public trust and responsible AI deployment.

The future prospects and scopes of AI in Chemical Engineering are remarkably promising. AI technologies offer solutions to long-standing challenges, ranging from process optimization to safety enhancement and sustainable practices. However, addressing challenges and ethical considerations is vital to ensure responsible AI integration in the field. The dawn of AI in Chemical Engineering is upon us, heralding a new era of innovation, efficiency, and sustainability. As AI technologies continue to evolve, Chemical Engineering stands to benefit from unprecedented advancements and transformational possibilities.

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Name: SAUBHAGYA MUKHERJEE

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Year: 3rd Year

BIODEGRADABLE PLASTIC

The first question that rises before us in this topic is "What is biodegradable plastic?"

The term "biodegradable plastic" refers to a plastic that degrades due to biological (often microbial) action. Some (but not all) biodegradable plastics are compostable, which means they break down in controlled environments like compost (or anaerobic digestion) sites.

Different biodegradable polymers decompose under specific and tested settings (e.g., soil degradability, wastewater treatment plant degradability, etc.), but the majority require industrial composting facilities, which, as we'll show later, is their acceptable destination.

They may biodegrade in the open environment, but the rate at which this happens varies greatly, and relevant test procedures and standards are not well defined or widely accepted. Compostable plastics must also meet a number of other criteria, including fragmentation, lack of ecotoxicity, and threshold amounts of hazardous contaminants such as heavy metals. Biodegradable plastics are made from all-natural plant materials. These can include corn oil, orange peels, starch, and plants. Traditional plastic is made with chemical fillers that can be harmful to the environment when released when the plastic is melted down. With biodegradable plastic, you get a substance made from natural sources that does not contain these chemical fillers, and does not pose the same risk to the environment.

The focus of this essay is on compostable biodegradable plastics, with the term "compostable" being used frequently. The focus is on the fact that, from the perspective of sustainable waste management, what matters is the materials' end-of-life behavior.

Global production capacity for bioplastics reached 2.11 million tonnes in 2019, of which 55.5% is biodegradable plastics, roughly 1.17 millions tonnes[9]. polylactic acid (PLA) is prob- ably the most well known biodegradable plastic, but more than 20 groups of biodegradable plastic polymers exist. Of those 20, only 3 groups are produced on a commercial production scale: (i) starch blends; (ii) PLA; and (iii) polybutylene-based polymers, which include PBS (short for polybutylene succinate) and PBAT (short for polybutylene adipate terephthalate), which are mostly fossil fuel based. Nearly 95% of production capacity for biodegradable plastics is among these 3 groups. The production capacity of starch blends was approximately 450 thousand tonnes in 2019. Starch is inexpensive and readily available compared to other natural polymers with additional biodegradability, making it a popular material to develop biodegradable plastics. However, due to its poor water resistance and low strength[10], starch is often blended with other polymers to achieve needed mechanical properties. The commercial development of starch blends have gone through several phases. Early stage starch blends are to fill conventional nondegradable plastics (such as polyethylene or polypropylene) with starch, with the aim of increasing degradability as well as reducing cost. This type of starch blend is only partially biodegradable. Thermoplastic starch (TPS) 1 was developed in response to the need for a material that would fully biodegrade. Current starch blends are mainly TPS blending with other types of biodegradable plastics, though partially biodegradable starch blends still remain in many countries, often marketed as the "biodegradable starch plastic". PLA is relatively cheap with several attractive mechanical properties compared to other biodegradable polymers, which has made it a popular material. As of 2019, production capacity of PLA was approximately 290 thousand tonnes. Both starch blends and PLA production heavily rely on plant feedstocks, such as cassava, potato, corn, and sugar cane. Other feedstock sources have been researched and explored, such as agricultural byproducts, cellulosic materials, or greenhouse gases (i.e. carbon dioxide and methane), but the technology is still under development and agricultural products look set to remain as the main feedstock for starch blends and PLA in the near future.

Bioplastics will be a major component in the New plastic Economy. For plastics to thrive without harmful waste and negative environmental impact, a switch from a linear economy to circular economy is paramount.

The Ellen MacArthur Foundation released a comprehensive report in 2017 aimed at rethinking plastics role in our future, and new research earlier this year aimed at providing tangible actions for stimulating change. This foundation's mission is to "accelerate the transition to a circular economy" by working with businesses, governments and academia to build awareness-plastics are a prominent material in modern manufacturing given their high functionality with relatively low costs. In the past 50 years, their use has skyrocketed across all markets. But petroleum based plastics fall under the linear economic model creating significant economic and environmental drawbacks.

That's not to say plastics haven't been good for the economy, instead it's to point out the room plastics can grow in our economy. According to the Ellen MacArthur Foundation's research, $80-120 billion in plastic packaging material is lost, every year, to disposal and waste.

The foundation points out that since the launch of the first universal recycling symbol, only 14% of plastic packaging is collected globally for recycling. Current projections place more plastics in the ocean by weight than fish by 2050.

While this is alarming, plastics don't need to be pushed to the wayside. Instead , with innovation, plastics can be redesigned and conformed into the circular economy to foster growth, reduce waste and improve their environmental impact.

Plastics have become common place manufacturing materials that find applications in a variety of industries, from packaging to the production of toys, from grocery bags to plastic cutlery, from straws to 3D printed rocket nozzles. Chemically, plastics are high molecular weight polymers typically comprising between 1000 to 10000 monomeric repeating units. Conventional petroleumbased synthetic plastics are produced in a series of steps, the first of which is the distillation of crude oil in an oil refinery. This process separates and fractionates the heavy crude oil into groups of lighter components, called segments. Each segment is a mixture of polymeric hydrocarbon chains, which differ in terms of size and structure. One of these fractions, naphtha, is the crucial component needed to generate monomers such as ethylene, propylene, and styrene to produce plastics. These monomers form plastics through polyaddition and/or polycondensation aided by specific catalysts. However, this conversion produces pollutants and greenhouse gases such as carbon dioxide (C02), thus contributing to environmental pollution and global warming. Moreover, several petroleum-based plastics are nonbiodegradable, which leads to their persistence at the site of disposal and harms the environment . Over two recent decades, several studies have suggested alternatives to the conventional petroleum-based plastics. One such alternative is bioplastics, which are polymeric compounds that are both functionally like synthetic plastics and largely environmentally sustainable. However, bioplastics are surrounded by myths, for example, all bioplastics are biodegradable and good for the environment. The truth is that some bioplastics may contribute significantly to global warming, pollution, and drastic land use change. Still, while many reviews discuss bioplastics, few comprehensively and simultaneously address the positive and negative dimensions of bioplastic use for the environment. Similarly, some reviews have separately focused on a comparative analysis of bioplastics and conventional fossil fuel-based plastics, specific bioplastics such as polyhydroxybutyrate (PHB), degradation of bioplastics, bioplastic waste management and recycling, and so on, without discussing these concepts in conjunction. Reviewing these concepts, therefore, in relation to one another is important to achieve a comprehensive understanding of the state of the art in the field of bioplastics. Furthermore, recently developed bioplastics, such as chitinbased and mycelium-based bioplastics, have not been significantly discussed in the literature despite their potential industrial value.

Throughout their lifecycle, petroleum-based plastics are associated with many environmental problems, including greenhouse gas emissions, persistence in marine and terrestrial environments, pollution, etc. On the other hand, bioplastics form a rapidly growing class of polymeric materials that are commonly presented as alternatives to conventional petroleum-based plastics. However, bioplastics also have been linked to important environmental issues such as greenhouse gas emissions and unfavorable land use change, making it necessary to evaluate the true impact of bioplastic use on the environment. Still, while many reviews discuss bioplastics, few comprehens ively and simultaneously address the positives and negatives of bioplastic use for the environment. The primary focus of the present review article is to address this gap in present research. TO this end, this review addresses the following questions: (1) what are the different types of bioplastics that are currently in commercial use or under development in the industry; (2) are bioplastics truly good for the environment; and (3) how can we better resolve the controversial impact of bioplastics on the environment? Overall, studies discussed in this essay show that the harms associated with bioplastics are less severe as compared to conventional plastics. Moreover, as new types of bioplastics are developed, it becomes important that future studies conduct thorough life cycle and land use change analyses to confirm the eco-friendliness of these new materials. Such studies will help policymakers to determine whether the use of new-generation bioplastics is indeed beneficial to the environment.

The conclusion is that biodegradable plastics are a part of the solution to waste accumulation but that their efficacy will depend on the co-emergence of affordable waste sorting technology and investments in organic waste handling facilities. Significantly, this work develops the idea that there are a range of target plastic products and materials where substitution with biodegradable plastics would be the most effective way to address the issue of plastic solid waste accumulation. These can be determined by considering material flows and identifying the materials most likely to be mismanaged or not practically recyclable.

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BIOPROCESS TECHNOLOGY

INTRODUCTION:

Bioprocess technology is engineering technology used in bioprocess engineering. Bioprocess technology refers to the use of living organisms or their components, such as cells, enzymes, or microorganisms, to produce valuable products or carry out specific processes. It plays a crucial role in various industries, including pharmaceuticals, biotechnology, food production, and environmental management. Bioprocess technology involves techniques like fermentation, cell culture, and genetic engineering to optimize the production of bioproducts such as pharmaceuticals, biofuels, enzymes, and more. It's a vital field for sustainable and eco-friendly production processes

While bioprocess engineering involves engineering innovation in biotechnology industry to create bio-product. This engineering involves proficiency in chemical and biological engineering. Bioprocess technology includes process that turns innovation in life-science into practical products that will meet the demand of the society.

All the bioprocess technologies involve process that could be divided into 3 stages:

- **STAGE –I (UPSTREAM):-**This process includes cleaning the air, sterilizing, removing particulates and inhibiting compounds from liquid medium and more. One of the important part of this stage is microorganism cultivation. Microorganism Cultivation involves the selection and cultivation of the specific microorganism, such as bacteria, yeast, or algae, needed for the desired byproduct.
- **STAGE-II (FERMENTATION):-** This process includes using biological agents like microbes to transform substrate into the desired product. Here microorganisms are

grown in a controlled environment, often in bioreactors, where they consume nutrients and produce the desired product, which could be a metabolite, protein, or enzyme.

- **STAGE-III (DOWNSTREAM):-**This process includes separating the cells from the fermentation broth, purifying and concentrating the desired product and discarding or recycling the trash. Downstream process includes:
  - Harvesting: The cultivated microorganisms or cells are separated from the fermentation broth.
  - Cell Disruption: If necessary, cells are broken open to release the intracellular product.
  - Purification: Various techniques, such as filtration, chromatography, and centrifugation, are used to purify and isolate the desired product from impurities.
  - Concentration: The purified product is concentrated to increase its potency or reduce its volume.
  - Formulation: The final product may undergo formulation steps, such as mixing with stabilizers or excipients, to enhance its stability and usability

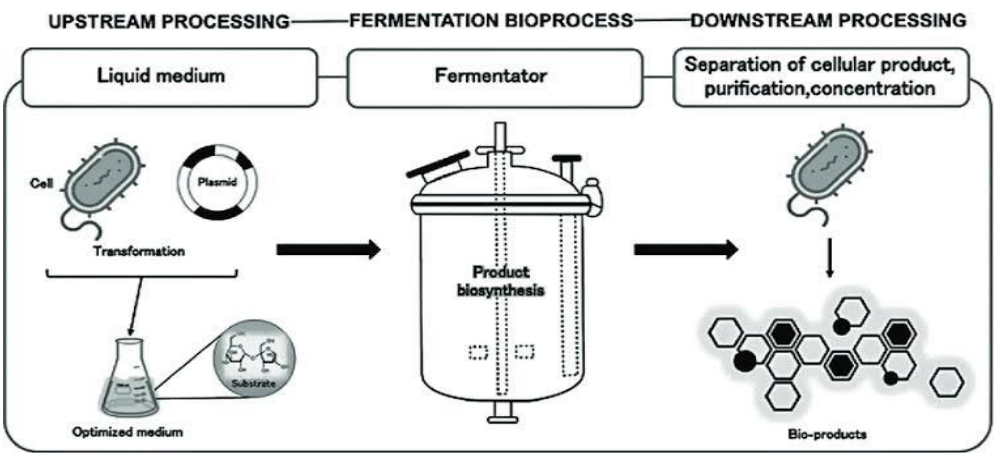

FIG-1:- Stages of bioprocess technology.

Other than these 3 main stages there are several other stages which are just as important. These include:

- **<u>QUALITY CONTROL:</u>** The product's quality is rigorously tested to ensure it meets specified criteria, such as purity, potency, and safety.
- **<u>PRODUCT RECOVERY AND STORAGE:</u>** The final product is collected, packaged, and stored under appropriate conditions to maintain its quality until distribution.
- **<u>WASTE TREATMENT:</u>** Proper disposal or treatment of waste generated during the bioprocess to minimize environmental impact.
- **<u>SCALE-UP AND OPTIMIZATION:</u>** The entire process is often scaled up from laboratory-scale to commercial-scale production, and optimization is ongoing to maximize yields and efficiency.
- **<u>REGULATORY COMPLIANCE:</u>** Ensuring that the bioprocess complies with regulatory requirements and standards, particularly in industries like pharmaceuticals and food production.

These stages may vary depending on the specific byproduct and the industry in which bioprocess technology is applied. The goal is to efficiently produce high-quality bioproducts while minimizing costs and environmental impact

<u>RELEVANCE UNDER CURRENT SCENARIO:</u>

Bioprocess technology has immense relevance under current scenario as bioprocess technology remains vital in addressing current global challenges, from healthcare to sustainability. Its adaptability, potential for innovation, and role in supporting a more environmentally conscious approach to production make it a cornerstone of various industries in the present and foreseeable future.

Some of the example of its relevance includes:-

- **<u>PHARMACEUTICALS</u>:-** To help develop medicine that are safe to use, bioprocess engineers works in research and development for the pharmaceutical industry. They examine different substance to create vaccine, medicinal therapy, etc. The development and manufacturing of vaccines during COVID-19 is the most pertaining example of this.

- **BIOMEDICINE:-**Bioprocess engineers frequently work in the biomedical field, where they could design or develop medical tools or software. These engineers might also create technologies for easier medicine administration and life support system. A bioprocess engineer can create a synthetic substance that medical professionals can utilize to 3D print organs for transplantation
- **AGGRICULTURE & FOOD INDUSTRY:-** Bioprocess engineers can create genetically modified organism that can be used in agriculture. These organism are modified in such a way so that it has characteristics desired by people like disease resistance, weight gain, etc. These engineers also examine ingredients, preservatives and nutrients to improve quality and shelf life of food.
- **PANDEMIC PREPAREDNESS:-** The COVID-19 pandemic highlighted the importance of bioprocesses in responding to health emergencies, leading to increased focus on biomanufacturing capabilities.
- **ENVIRONMENTAL CLEANUP:-**Bioprocesses, such as bioremediation, are used for environmental cleanup efforts, addressing pollution and restoring ecosystems.

ECONOMIC VIABILITY:

Recent years have seen a rise in the use of bioprocess technology due to its advantages for the environment and society. Additionally, because of the pandemic, every nation has begun investing in bioprocess technology after realizing its benefits. A circular economy that seeks to both build a sustainable environment and achieve economic viability is promoted by bioprocess technology. With this technology, the final product and any of its by-products are used as raw materials thus creating a circular economy. Bioprocess technology, with its focus on sustainable and environmentally friendly production methods, can contribute significantly to a circular economy by reducing waste, conserving resources, and minimizing environmental impact. It aligns well with the goal of creating a more sustainable and regenerative economic system.

Through a circular economy, bioprocess technology aims to bring positive changes by:

- **USING BIO-BASED FEEDSTOCK:** Bioprocesses often use renewable and bio-based feedstocks, such as agricultural residues, algae, or waste streams. These feedstocks can replace or reduce the dependence on fossil fuels, aligning with circular economy principles.
- **WASTE VALORIZATION:** Bioprocesses can convert organic waste materials into valuable products. For example, food waste can be transformed into biofuels or bioplastics, reducing landfill waste and utilizing resources more efficiently.
- **BIODEGRADABLE PRODUCTS:** Bioprocesses can produce biodegradable materials and products, which can be returned to the environment without harm, reducing pollution and contributing to a circular approach.
- **CLOSED-LOOP SYSTEMS:** Bioprocesses can be integrated into closed-loop systems, where waste products from one process become inputs for another. For instance, byproducts from one bioprocess can serve as substrates for another, minimizing waste generation.
- **BIOREMEDIATION:** Bioprocesses can help remediate polluted environments by using microorganisms to break down contaminants. This approach can restore ecosystems and reduce the negative environmental impact of pollution.
- **RECYCLING AND REUSE:** Bioprocesses can produce materials that are easily recyclable or reusable. For instance, biodegradable plastics made through bioprocesses can be recycled into new bioplastics

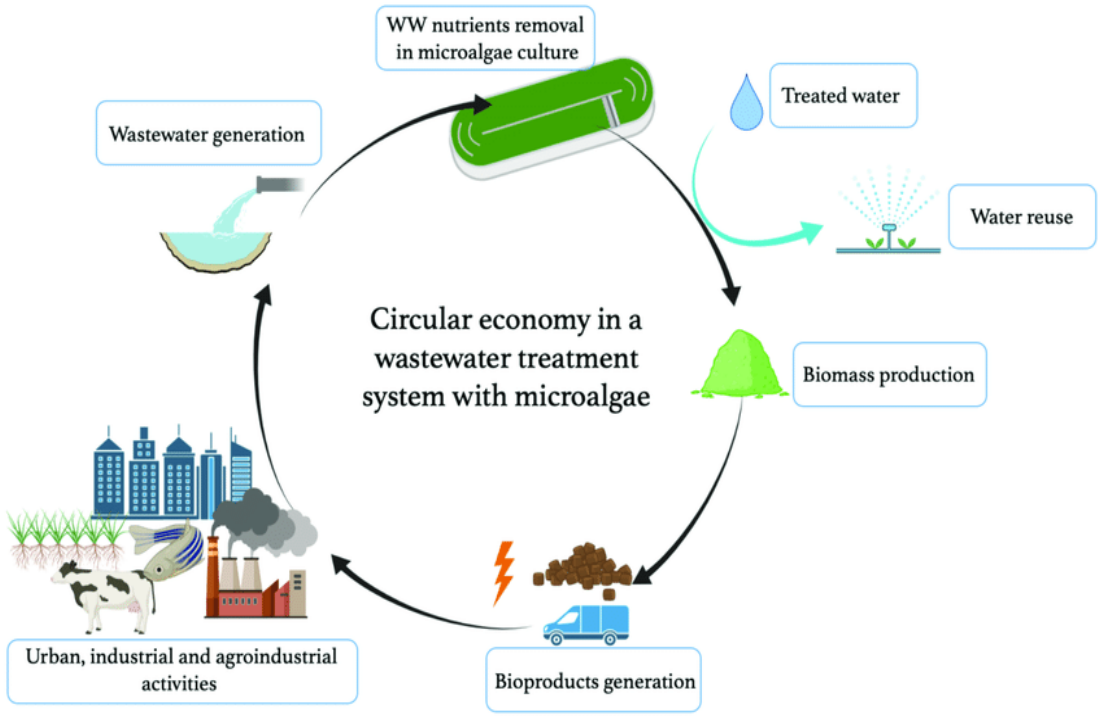

FIG-2:-Circular economy by bioprocess.

IMPACT ON ENVIRONMENT:

Bioprocess technology tries to create a positive impact on the environment by various technologies. Some of this includes:

- **BIOPESTICIDES:-** Bioprocess technology has created several environmental friendly and biodegradable pesticides. One of the prevalent examples is the creation of BT (Bacillus Thuringiensis) pesticides. This pesticide is biodegradable and prevents pesticides related pollution, bioaccumulation, biodiversity losses, etc.
- **BIOREMEDIATION:-**Bioprocess technology tries to indulge in bioremediation. Bioremediation transform toxic substance into less toxic substance in order to prevent pollution.
- **WASTE-TREATMENT:-**In recent years there has been an increasing production of industrial and household waste which is toxic and harmful to the environment.

Through bioprocess several technologies are created for treating these waste before releasing it to the environment.

- **<u>BIODEGRADABLE PRODUCTS :-</u>**Bioprocesses can produce biodegradable materials and products, which can break down naturally in the environment, reducing long-term pollution
- **<u>REDUCED CARBON FOOTPRINT:-</u>** Bioprocesses often have a lower carbon footprint compared to traditional chemical processes, especially when using renewable feedstocks. This can help reduce greenhouse gas emissions and combat climate change.
- **<u>RENEWABLE ENERGY:-</u>** Bioprocesses can produce biofuels, such as biodiesel and bioethanol, which can replace fossil fuels and reduce dependence on non-renewable resources.

It's important to note that the environmental impact of bioprocess technology can vary widely depending on factors such as the specific application, technology used, and the degree of sustainability practices employed. To maximize the positive environmental impact, it's crucial to adopt sustainable and eco-friendly practices, minimize resource consumption, and carefully manage waste streams. Regulatory oversight and best practices can help harnessing the benefits of bioprocess technology

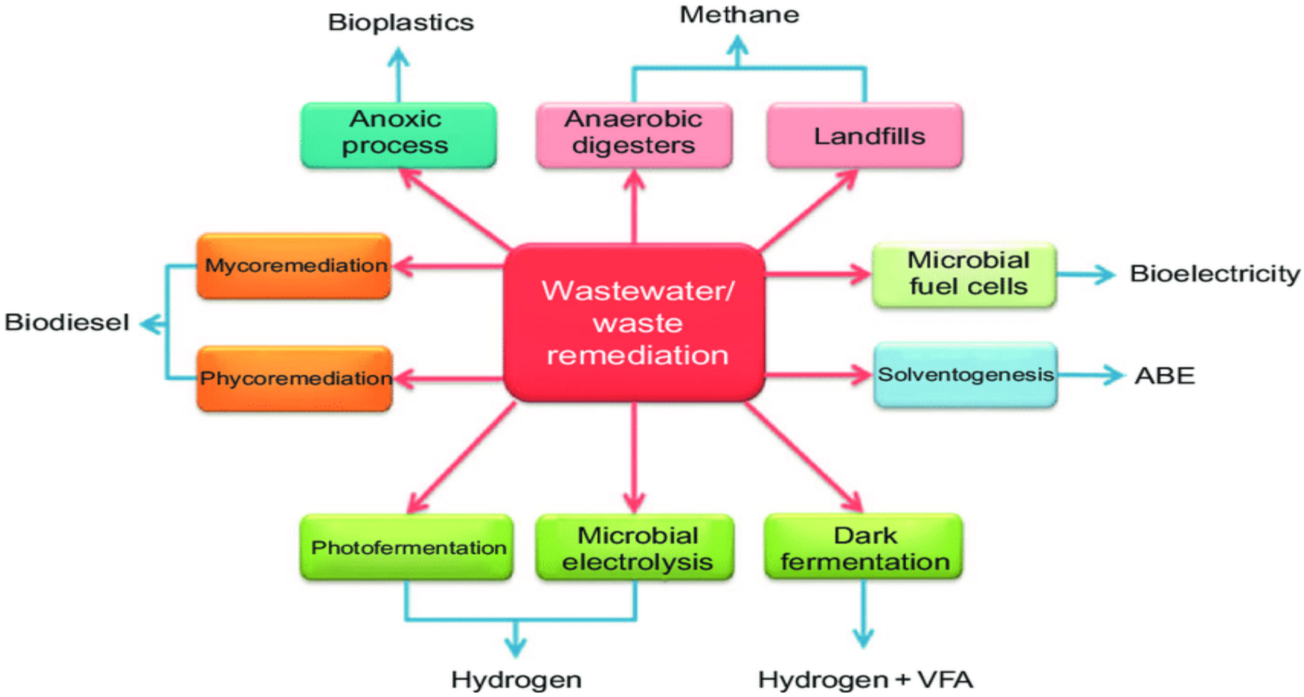

FIG-3:-Waste treatment by bioprocess.

CONCLUSION:

In conclusion, bioprocess technology is a versatile and essential field with wide-ranging applications in various industries, including pharmaceuticals, biotechnology, food production, and environmental management. It harnesses the power of living organisms and their components to produce valuable products and carry out specific processes.

Bioprocess technology represents a promising avenue for addressing various societal challenges, from providing essential medicines to reducing environmental pollution. As technology and knowledge in this field continue to advance, it is likely to play an even more significant role in shaping a sustainable and efficient industrial landscape.

The impact of bioprocess technology on the environment and society could be tremendous over long term. The COVID-19 pandemic highlighted the importance of bioprocess technology and the urgent need to invest in to enrich the society and environment and to combat such pandemic in the future more efficiently.

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NAME: SNEHA BHATTACHARYA

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YEAR:- 3RD YEAR

Low-frequency unsteadiness in shock wave–turbulent boundary layer interactions

Introduction

The interaction between a shock wave and a boundary layer often leads to extremely detrimental effects, especially if the shock is strong enough to separate the boundary layer. When this happens, there occurs a rapid growth of the dissipative region along with a dramatic intensifying of turbulent fluctuations with the frequent occurrence of buffeting. The shockwave turbulent boundary layer is studied using Global Stability Analysis based on a separation of scales between the low-frequency, large-scale motions and the turbulent fluctuations.

A shockwave turbulent Boundary flow Interaction(STBFLI) is a major problem of fluid mechanics, which is also a major field of study in aerodynamics and propulsion of high-speed flight vehicles(Clemens & Narayanaswamy 2014*).

In this theory, we examine the intrinsic and extrinsic dynamics of STBLIs to reveal the nature of the low-frequency unsteadiness using GSA and resolvent analysis under a unified framework, in which low-frequency, large-scale movements are considered as coherent structures and turbulent fluctuations are closed by turbulence designing.

Theory

The considered geometry is a compression corner with a ramp angle of $\alpha = 25°$(see fig1). A 3-D Cartesian coordinate system is constructed with the origin at the corner, the x direction along the flat plate, the y direction perpendicular to the flat plate and the z direction coming out of the plane perpendicular to both the axes. The flow conditions are taken from the experiments of Zheltovodov et al. (1990). The lowRe case has $M\infty = 2.95$ and $Re\delta = 63\ 560$

with δ = 2.27 mm measured 15.4δ upstream of the corner. The free-stream density is 0.314 kg m^{-3}, and the free-stream temperature is 108 K. The highRe case has M_∞ = 2.88 and Re_δ = 132 840 with δ = 4.1 mm measured 8.04δ upstream of the corner. The free-stream density is 0.368 kg m^{-3}, and the free-stream temperature is 114.8 K.

Computational Analysis

Governing equations

The flow is governed by the 3-D compressible RANS** equations as

$\partial U/\partial t = N(U)$, eq(3.1)

where U is the vector of conservative variables and N is the nonlinear RANS** operator.

**RANS: Reynold's Average Navier-Stokes equation. They are the time averaged equations of fluid motion flow.

Air is modelled as a calorically perfect gas with a specific heat ratio of 1.4 and a Prandtl number of 0.72. Sutherland's law is used to calculate the molecular viscosity. The Reynolds stresses are modelled using the Boussinesq assumption. The eddy viscosity is obtained using the Spalart–Allmaras (S–A) turbulence model (Spalart & Allmaras 1992) with the modification of Edwards & Chandra (1996). The reason why the S–A model chosen 2-fold.

Flow solver

The 2-D and 3-D flow movements are solved using an in-house finite volume solver known as the PHAROS(Hao, Wang & Lee 2016; Hao & Wen 2020). The inviscid fluxes are solved by the modified Steger-Warming scheme, whereas the viscous fluxes are calculated by second order central difference.

Global Stability Analysis

It is assumed that vector U can be decomposed into a 2-D steady base flow (denoted by an overbar) and a small-amplitude 3-D unsteady perturbation (denoted by a prime) as

U(x, y,z, t) = ¯U(x, y) + U (x, y,z, t). eq(3.2)

Substituting (3.2) into (3.1) and neglecting the higher-order terms leads to the governing equations of the perturbation as:

∂U∂t = L(¯U)U , eq(3.3)

where L is the linearized RANS operator. The expression of the linearized source term in the S–A model is given by Crouch(2007). In other words, the turbulence model equation is also linearized without simplifications such as the frozen eddy-viscosity approach (cf. Carini et al. 2017). The perturbation U is further assumed to be in the following modal form:

U (x, y,z, t) = ˆU(x, y) exp[iβz − i(ωr + iωi)t], eq(3.4)

Results

The solutions to base flow are obtained using the PHAROS(Hao, Wang & Lee 2016; Hao & Wen 2020) for different Reynold's number(Re) and different ramp number(α) respectively. The streamwise velocity contours superimposed with the isoline of ¯u/u∞ = 0.99 and the dividing streamline are displayed in figure 2 for the lowRe and highRe cases at α = 25°. Both cases exhibit large flow separation with the separation shock penetrating deeply into the incoming boundary layer.

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2nd Year

PRACTISING SUSTAINABILITY IN CHEMICAL ENGINEERING

Chemical engineering is a branch of core engineering that deals with the manufacturing of various chemical processes. It includes setting up and designing plants where these processes take place. With the increase in the eventual shortage of natural resources to work with, various new technologies are rising in this field to make sustainable development work. Making things worthwhile from what we set aside as waste in our daily lives, is what is gaining immense recognition nowadays.

The following two case studies are some of the most common cases of sustainable development in the field of chemical engineering.

<u>The hidden potential of sewage water</u>

A chemical engineering Ph.D. candidate at the University of Toronto named Sara Abu-Obaid found out that there is an effective way to utilize wastewater. She found a unique way to sieve out useful elements like phosphorous and ammonia from the wastewater of the sewage plants. She encourages us to find the potential within what we consider as least useful to us. Finding sustainability in discarded materials is the prime holistic way of approaching life and its ways. Sara Abu-Obaid under the mentorship of Professor Ramin Farnood did research and found an eco-friendly way to reuse the nutrients sieved from wastewater. She talks about using a technologically advanced membrane containing inorganic elements to strain out useful elements from sewage. She explains how to extract the nutrients completely and utilize them at their most in chemical plants. The inorganic membrane is made up of akageneite and zeolite 13X. These elements have high adsorption power for phosphates and ammonium. No external ways of separating are being applied in this technique. Instead, the membrane itself is built in a way that will separate the useful elements from the non-useful ones. Two steps are followed in this entire process:

- Adsorption of the useful particles (ammonium, phosphate) from the wastewater occurs.
- The membranes are washed with sodium hydroxide solution to regenerate the particles.

It proved highly effective with the removal of 84 percent of ammonium and 100 percent of phosphate. More research is going on to adopt this technique and ensure its application on a large scale.

Recyclable printed electronics in the world of chemical engineering

The engineers of Duke University came up with a process that uses transistors running on water and not harsh chemicals and which are fully recyclable. Reducing the impact of harmful chemicals on our environment is the main motive behind this process. Aaron Franklin, the professor at Duke University who led this process, elaborates how in a cyclical process this system can be put to work.

- Firstly, the device needs to be rinsed thoroughly with water.
- Then it has to be dried in relatively low heat.
- After drying, it will be ready for printing again.

When chemicals were being used in place of water, the density of the output seemed to change. However, after the replacement, the density remains the same. Some surfactants are used to prevent the carbon nanotubes from clumping and the various layers of paper from getting stuck to the previous one. In the general procedure, these surfactants are removed using chemicals and/or high-temperature environments using up a lot of energy. Franklin wanted to reduce the harmful effects these procedures and substituents have on our environment. Therefore, he came up with this system where even the ink is sustainably beneficial to our environment along with fully functional water-based electronic devices. He has also proven that the carbon-based nanotubes used in printers along with graphene can be fully recycled with the potential to be reused. The substance, nano cellulose, is made up of wood and hence is biodegradable. Therefore, it can be recycled. This process does take up a lot of water but it is still less than what is required to deal with toxins and other harmful chemicals. This procedure is still gaining complete recognition and funding but it is making a huge impact. Hence, e-waste being recycled is one of the most used and discussed methods in the current generation, in the world of printed electronics.

Be it any field of work, sustainable development is required to give our future generations the resources they deserve and a healthy environment to live in.

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Year: 1st Year

3D printing, also known as Addictive Manufacturing (AM) has become one of the most revolutionary and powerful tools serving as a technology of precise manufacturing of chemicals from laboratory scale to large scale production. The introduction of 3d painting in chemical industry has opened a new path in research of printed materials and equipment. Mainly there are three reasons why 3d printing industry growing rapidly. Firstly, the low cost of materials making it affordable. Secondly the rate at which materials can be printer is getting faster. Lastly more types of materials can now be used with new 3d printers. To carry out 3d printing, one needs a personal computer connected to a 3d printer that's it. All you need to do is design a 3d model of the required object on computer-aid design (CAD) software such as Tinker cad, Blenders, SolidWorks, Autodesk, 3D slash, and many more and press 'print'. The 3D printer will do the rest of the job according to the design.[1]

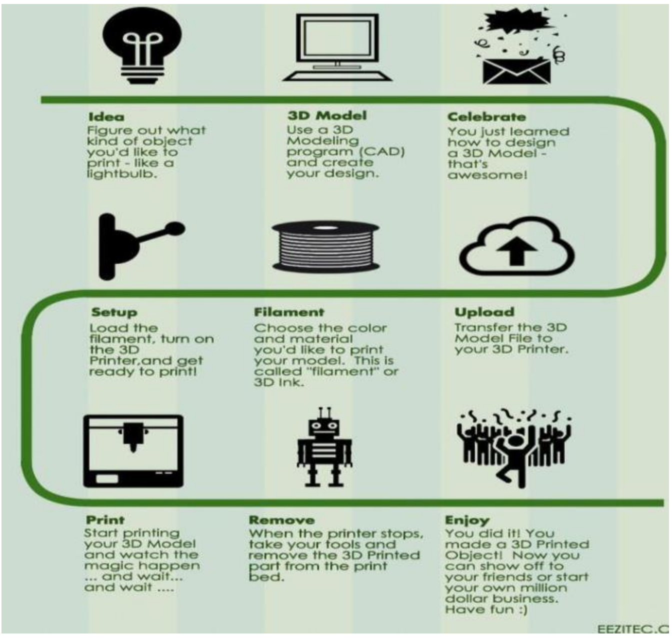

Figure 1: Steps of 3D printing

Only a month ago (18 August) India's first 3D printed post office in Bengaluru was inaugurated by the Union Minister Ashwini Vaishnaw made a huge hit in internet. Multinational company Larsen and Toubro Limited built the post office with the technological support from IIT Madras under the guidance of Professor Manu Santhanam, building Technology and Construction Management Division, Department of Civil Engineering. Its construction was completed in just 43 days. At the peak of the Covid-19 pandemic in 2020, the healthcare industry used 3D printers to make much-needed medical equipment, like swabs, face shields, and masks, as well as the parts to fix their ventilators.[2]

The term 3D printing originally referred to a powder bed process employing standard and custom inkjet print heads, developed at MIT by Emanuel Sachs in 1993 and commercialized by Solingen Technologies, Extrude Hone Corporation, and Z Corporation. Year 1993 also saw the start of an inkjet 3D printer company initially named Sanders Prototype, Inc and later named Solids cape, introducing a high-precision polymer jet fabrication system with soluble support structures, (categorized as a "dot-on-dot" technique). In 1995 the Fraunhofer Society developed the selective laser melting process.[3]

Invented in 1980s, 3D printing burst into the mainstream around the 2010s. The technology however, at the time was expensive, slow and prone to making errors. In recent years, some of these flaws have been done away with, making 3D printing more prevalent than ever before. For instance, it's being used in automotive and aerospace sectors to make parts of cars and rockets respectively. According to the data published by Statista, the global market size of 3D printing products and services was $12.6 billion in 2020 and is anticipated to reach $37.2 billion by 2026. In India the 3D printing market has grown exponentially over the last few years. In 2022, the 3D printing market was at $92.34 million. The forecast says it will grow at a CAGR of 20.33% by 2028.[4] The government is targeting 50 India specific technologies to be developed on 3D printing, 100 new start-ups, 500 products, 10 existing and new manufacturing sectors and creation of one lakh new skilled manpower. As the part of the strategy the government would address key sector specific technical challenges for making 3D printing economically variable for MSMEs.[5]

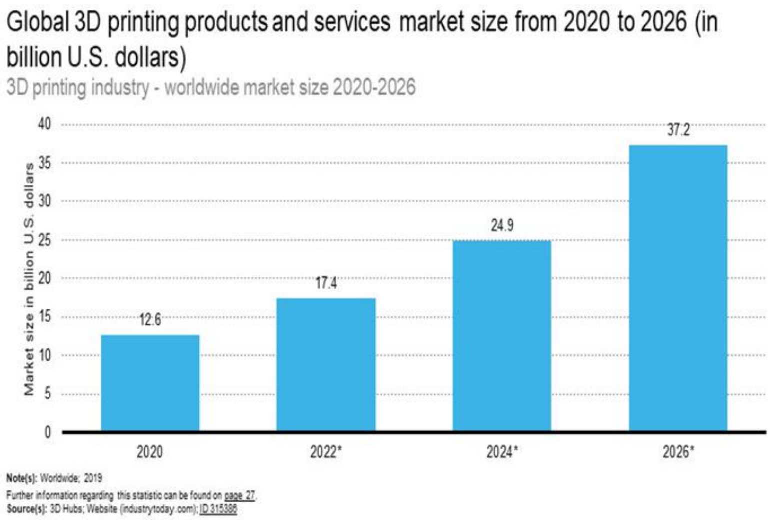

Figure 2: Market overview

The common principle that includes all additive techniques is that fabrication of objects is done with layer-by-layer synthesis. The methods of 3D printing differ through layer fusion and layer formation. Initially, additive manufacturing technology was mostly utilized for prototype designing and making future products model. Presently, prototyping is just one major type of application of 3D printing. Other methodologies of modern additive technique have been developed for final functional items manufacturing, which is known as direct digital manufacturing or rapid manufacturing. (a)Binder jetting (BJ), (b) directed energy deposition (DED), (c) material extrusion, (d) material jetting (MJ), (e) powder bed fusion, (f) sheet lamination (SL), and (g) vat photopolymerization (VP), according to the standard of demonstrates these are the seven types addictive technologies.

□ *Binder jetting*- This is a type of technology for 3D printing in which powered materials are used to make the shape of the object. This technology has some drawbacks such as high roughness of surface, narrow range of materials for construction, etc.

□ *Directed energy deposition*- This methodology is utilized as the fed of metal in the form of a stream of powder which is operated by an inert gas, from coaxial to a beam of laser, towards the pointing at the beam of laser. To achieve higher accuracy of manufacturing and higher quality of surface, this technology is integrated with conventional subtractive processing method with the help of machine of computer numerically controlled.

 Material Extrusion- This technique is based on material extraction through the nozzle of the extruder. The extruder always moving with each layer's geometry and regularly provides the material from a thin orifice. This methodology includes direct ink writing and fused deposition modeling methods.

 Material Jetting- It is based on the creation of the object in each layer by jet deposition for the materials of construction by the nozzles array in the head of the 3D printer, in other words, the liquid states of materials occur initially.

 Powder Bed Fusion- This technique is based on the fusion or sintering of a powder with an electron or laser beam. The materials of construction in this method are glass, metals, composites, ceramics, and other materials, which are capable of finely dispersed powders.

 Sheet Lamination- This type of 3D printing includes ultrasonic additive manufacturing, selective deposition lamination, and laminated object manufacturing. This approach might be applied to a different range of materials such as textiles, paper, composite materials, metals, and plastic. This process of printing does not include any phase transitions of the main materials of construction.

 Vat Photopolymerization- It is the set of additive manufacturing methodologies based on curing a monomer of the liquid type under the ultraviolet radiation action. In some cases, infrared or visible radiation is utilized.[5]

1. Prototyping and Product Development: 3D printing is instrumental in product design and development. Designers and engineers can quickly create physical prototypes to test form, fit, and function. It reduces the time and cost involved in traditional prototyping methods, such as CNC machining or injection molding. In terms of prototyping, many university programs are turning to printers. There are specializations in additive manufacturing one can attain through architecture or industrial design degrees. Printed prototypes are also very common in the arts, animation and fashion studies as well.[6]

2. Aerospace: Aerospace companies use 3D printing for producing lightweight components with complex geometries. This reduces the weight of aircraft and spacecraft, leading to fuel savings and improved performance. Components like turbine blades, brackets, and even entire rocket engines can be 3D printed. In space missions, 3D printers are used to produce tools and spare parts on-demand. It reduces the need to transport a vast inventory of items from Earth, making space exploration more feasible. By 2019, a commercial-built recycling facility was scheduled to be sent to the International Space Station to take in plastic waste and unneeded plastic parts and convert them into spools of feedstock for the space station additive manufacturing facility to be used to build manufactured-in-space parts.[7]

3. Medical and Healthcare: Personalized medicine is a significant application. Surgeons can use 3D printing to create patient-specific anatomical models to plan complex surgeries. Custom prosthetic limbs and orthopedic implants are produced for patients, leading to better comfort and functionality. Dental labs use 3D printing to manufacture dental crowns, bridges, and dentures. This technology enhances precision and allows for quicker production. Clear aligners for orthodontic treatments are also 3D printed. Nowadays, Additive Manufacturing is also employed in the field of pharmaceutical sciences. Different techniques of 3D printing (e.g. FDM, SLS, Inkjet Printing etc.) are utilized according to their respective advantages and drawbacks for various applications regarding drug delivery.[8]

4. Automotive: The automotive industry employs use 3D printing for rapid prototyping of vehicle parts and components. It allows for the creation of lightweight parts, customized car accessories, and even concept cars. Industries can 3D print spare parts for machinery and appliances, reducing downtime and costs. This is particularly useful for obsolete or hard-to-find parts. *Urbee* [9]is the name of the first car in the world car mounted using the technology 3D printing (its bodywork and car windows were "printed"). Created in 2010 through the partnership between the US engineering group Kor Ecologic and the company Stratasys (manufacturer of printers Stratasys 3D), it is a hybrid vehicle with futuristic look.

5. Architecture and Construction: In construction, 3D printing is used for creating architectural models and scale prototypes. There are experiments with 3D printing entire buildings, where structures are constructed layer by layer, reducing construction waste and time.

6. Consumer Products: 3D printing services enable consumers to customize products such as phone cases, figurines, and home decor items. Users can personalize designs to their preferences.

7. Fashion and Jewelry: Fashion designers and jewelers use 3D printing for creating intricate and unique designs that are difficult to achieve with traditional manufacturing. It allows for the production of lightweight and intricate jewelry pieces.

8. Art and Sculpture: Artists embrace 3D printing for creating intricate sculptures and installations. The technology offers new creative possibilities in terms of form and structure. At the 3DPrintshow in London, which took place in November 2013 and 2014, the art sections had works made with 3D printed plastic and metal. Several artists such as Joshua Harker, Davide Prete, Sophie Kahn, Helena Lukasova, Foteini Setaki showed how 3D printing can modify aesthetic and art processes. In 2015, engineers and designers at MIT's Mediated Matter Group and Glass Lab created an additive 3D printer that prints with glass, called G3DP. The results can be structural as well as artistic. Transparent glass vessels printed on it are part of some museum collections.[10]

Figure 3: A 3D printed glass

9. Food Industry: While still in its early stages, 3D printing is explored for creating detailed food designs and prototypes. It may have potential applications in high-end culinary experiences and personalized nutrition. A food-tech startup Novameat from Barcelona 3D-printed a steak from peas, rice, seaweed, and some other ingredients that were laid down crisscross, imitating the intracellular proteins [11]

10. Environmental Applications: 3D printing can be used to recycle and reuse materials, contributing to a more sustainable manufacturing process. Sustainable product designs and structures are explored. n Bahrain, large-scale 3D printing using a sandstone-like material has been used to create unique coral-shaped structures, which encourage coral polyps to colonize and regenerate damaged reefs. These structures have a much more natural shape than other structures used to create artificial reefs, and, unlike concrete, are neither acid nor alkaline with neutral pH.[12]

In this review, there are rich landscape of 3D printing in manufacturing industry. At present, 3D printing technology is beginning in the manufacturing industries, it offers many benefits to the people, company and government. Therefore, more information is needed to progress on ways to enhance the adoption of 3D printing technology. The more information about 3D printing technology will help the company and government to upgrade and improve the infrastructure of 3D printing technology. Thus, this paper is to overview the types of 3D printing technologies, materials used for 3D printing technology in manufacturing industry and lastly, the applications of 3D printing technology. In the future, researchers can do some study on the type of 3D printing machines and the suitable materials to be used by every type of machine.

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Delamination and Cracking in Colloidal Films: Mechanisms, Implications, and Mitigation

Abstract

Delamination and cracking in colloidal films are complex phenomena that significantly influence the performance and reliability of various applications across diverse industries. Delamination refers to the separation of the film from its substrate, while cracking involves the formation of fissures or fractures within the film. These issues are caused by a multitude of factors, including weak adhesion forces, thermal effects, mechanical stress, environmental factors, and substrate surface energy. Cracking, on the other hand, can be attributed to capillary forces, particle packing, drying rate, substrate interaction, particle size, and shape. The implications of delamination and cracking are far-reaching, affecting coatings, electronics, drug delivery systems, optical films, and flexible devices, among others. To mitigate these challenges, strategies such as adhesion enhancement, controlled drying, particle engineering, multilayer films, post-treatment processes, substrate modification, and stress relief layers are employed. Understanding and addressing delamination and cracking are essential for optimizing the performance of colloidal films and enhancing their functionality in various applications.

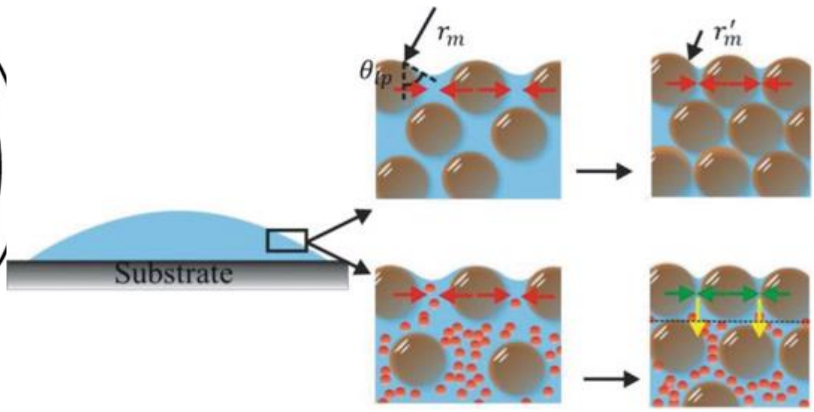

Fig. 1: Schematic diagram of Laplace pressure and osmotic pressure in a colloidal droplet

Introduction

Colloidal films, intricate assemblies of nanoparticles or microparticles suspended within a liquid medium, have emerged as remarkable materials with a multitude of applications across a wide array of industries. From advanced coatings to drug delivery systems and flexible electronics, the versatility of colloidal films has fuelled their adoption in diverse fields. However, as with any sophisticated technology, these films are not immune to challenges, and among the most prominent are delamination and cracking. Delamination, characterized by the detachment or peeling away of a colloidal film from its underlying substrate, and cracking, marked by the formation of fractures or fissures within the film, are issues that pose significant hurdles in realizing the full potential of colloidal films. The intricate interplay of forces, from adhesion to mechanical stress, and factors, such as particle properties and drying conditions, underpin the mechanisms behind these phenomena. A comprehensive understanding of the causes, consequences, and strategies for mitigating delamination and cracking is essential for harnessing the capabilities of colloidal films in a myriad of applications. In this exploration, we delve into the intricate world of delamination and cracking within colloidal films, uncovering the underlying mechanisms, elucidating their implications across industries, and illuminating strategies to combat these challenges. As we navigate through the complexities of colloidal film behaviour, we embark on a journey to unlock their full potential in shaping the technological landscape of tomorrow.

Delamination: Causes and Mechanisms

Delamination, the detachment or peeling away of a colloidal film from its substrate, can manifest spontaneously or result from external factors. The strength of adhesive forces between the film and the substrate significantly contributes to delamination. Weak adhesion forces, especially when subjected to thermal or mechanical stresses, can trigger spontaneous delamination. Temperature fluctuations can lead to the expansion or contraction of the film, which, if it differs in thermal expansion from the substrate, can induce delamination. Mechanical stress is a notable driver of delamination. The bending or stretching of the substrate can cause the film to detach, particularly during fabrication, handling, or operational conditions. Environmental factors, such as moisture and humidity changes, may weaken adhesion forces, rendering the film more prone to delamination. Surface energy mismatch between the film and substrate is another significant factor, influencing the propensity for delamination. Mismatched surface energies hinder proper adhesion and promote separation. The thickness of the colloidal film plays a critical role in delamination. Thicker films are more susceptible to delamination due to increased internal stresses and reduced adhesion to the substrate. As the film grows thicker, the mechanical forces it experiences during drying or operation become more pronounced, exacerbating the risk of delamination. Therefore, optimizing film thickness is essential to mitigate this issue.

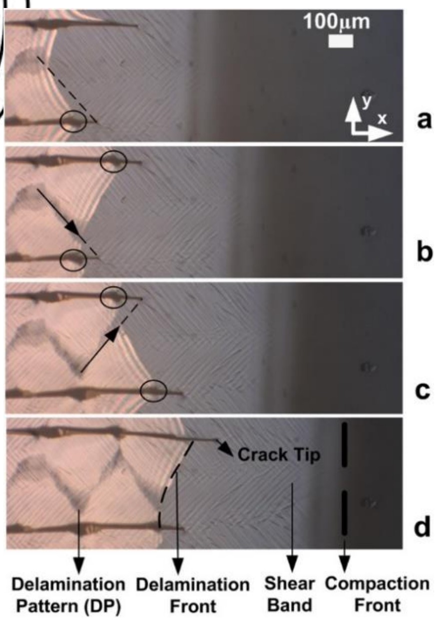

Fig. 2 Time lapse images of delamination taken using an inverted microscope in reflection mode.

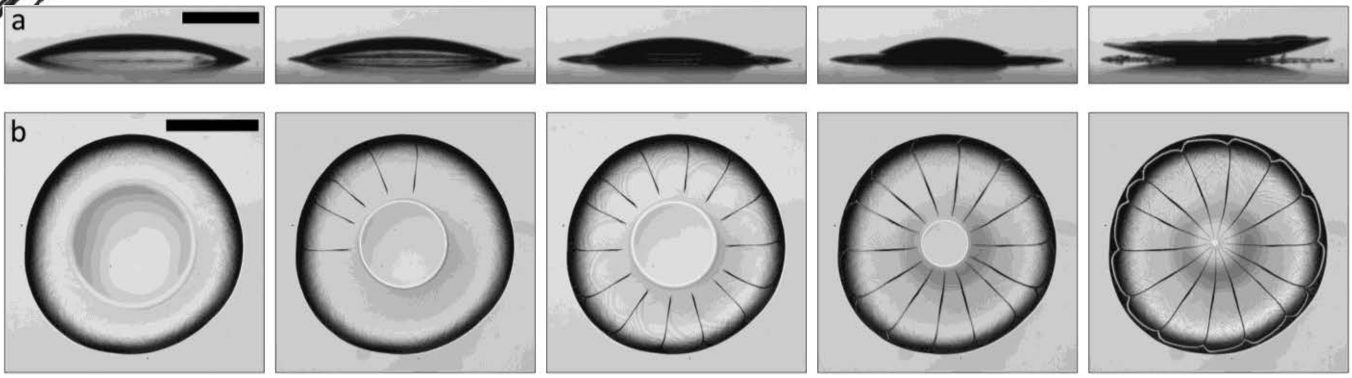

Fig. 3 Drying of colloidal suspension drop

Cracking: Causes and Mechanisms

Cracking within colloidal films, characterized by the formation of fractures or fissures, can arise during the drying process or due to mechanical stress. Several mechanisms contribute to cracking. Capillary forces, generated as the solvent evaporates from the film's surface, induce stress, potentially leading to the formation of cracks. This phenomenon is particularly pronounced in thin films where the ratio of surface area to volume is higher, making capillary forces more influential. The arrangement of colloidal particles within the film significantly influences cracking. Packing defects or voids within the film can serve as initiation points for cracks. The drying rate during film formation plays a pivotal role in crack development. Rapid drying results in differential drying rates across the film, creating stress gradients that can culminate in crack formation. The interaction between the colloidal film and the substrate also plays a role, with mismatched mechanical properties either promoting or inhibiting cracking, depending on the nature of the mismatch. The size and shape of colloidal particles further impact crack propagation. Irregularly shaped particles or larger particles tend to promote more extensive cracking, while well-shaped and smaller particles may reduce cracking tendencies. Particle engineering, involving the careful selection of particle properties, can be a powerful strategy for mitigating cracking in colloidal films.

Implications of Delamination and Cracking:

Understanding the implications of delamination and cracking in colloidal films is paramount for addressing their impact on various applications. In the context of coatings and surface engineering, delamination can compromise the film's protective properties, leaving the underlying substrate vulnerable to environmental factors or damage. Conversely, cracking can have aesthetic implications, affecting the visual appeal of coatings, and may also compromise the barrier functionality of the film. In the electronics industry, where colloidal films are employed in various components, delamination and cracking can lead to reduced performance and reliability. Integrated circuits, displays, and other electronic devices may experience malfunctions or even complete failure due to these issues. These implications extend to drug delivery systems as well, where delamination or cracking can alter drug release profiles, affecting the effectiveness of therapeutic treatments. Optical films, such as anti-reflective or interference coatings, are also affected by these issues. Delamination and cracking can impair the optical performance of these films, reducing their efficacy in enhancing light transmission or minimizing unwanted reflections. Moreover, in the realm of flexible electronics, delamination and cracking can result in electrical failures and a reduced lifespan for the devices, posing significant challenges to the development of flexible and wearable technologies.

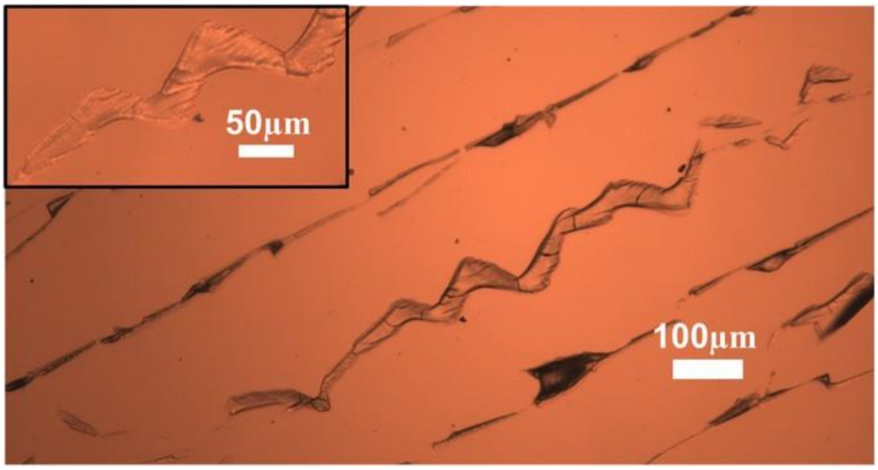

Fig. 4 Deposits left behind on the substrate after delamination of a silica film

Mitigation Strategies:

Mitigating delamination and cracking in colloidal films necessitates a multifaceted approach that addresses the underlying causes:

1. Adhesion Enhancement: Strengthening the adhesion between the colloidal film and the substrate is fundamental to preventing delamination. Surface treatments, the use of primers, or modifications to the film's composition can enhance interfacial interactions, bolstering adhesion.
2. Controlled Drying: Adjusting the drying conditions during film formation, including temperature and humidity, is essential to minimize capillary forces and stress buildup. Slowing down the drying process can reduce the risk of cracking.
3. Particle Engineering: Careful selection of particle size, shape, and surface properties can help reduce the film's susceptibility to cracking. By optimizing these parameters, engineers can enhance film cohesion and reduce cracking tendencies.
4. Multilayer Films: Creating multilayer films with varying properties can distribute stress more evenly across the film, reducing the impact of delamination or cracking. This approach involves designing layers to work in tandem and compensate for potential weaknesses in individual layers.
5. Post-Treatment Processes: Applying post-treatment processes, such as annealing or cross-linking, can further improve film cohesion and reduce the risk of delamination or cracking. These processes can strengthen the bonds within the film and enhance its overall integrity.
6. Substrate Modification: Modifying the surface of the substrate to enhance adhesion is an effective approach for mitigating delamination. Surface treatments or coatings on the substrate can create a more favourable environment for adhesion, reducing the likelihood of separation.
7. Stress Relief Layers: Introducing stress relief layers or buffer layers between the colloidal film and the substrate can absorb mechanical stresses, reducing the risk of delamination. These layers act as a cushion, helping to distribute and mitigate stress.

Conclusion:

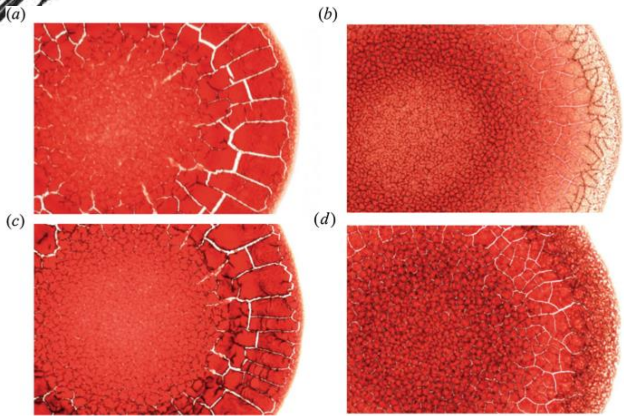

Fig. 5 Crack formation in drying blood drops

In the realm of colloidal films, where nanoparticles and microparticles coalesce within a liquid medium to create materials of unparalleled versatility, the challenges of delamination and cracking are multifaceted, demanding our attention and ingenuity. Throughout our exploration, we've unravelled the intricate mechanisms underpinning these phenomena and uncovered their far-reaching consequences across industries. Delamination, with its propensity to compromise the integrity of coatings and surface engineering applications, poses a formidable barrier. Cracking, on the other hand, disrupts not only the functionality but also the aesthetics of colloidal films, affecting optical and electronic components, drug delivery systems, and beyond. The implications are as diverse as the applications themselves, casting a shadow on reliability, performance, and even therapeutic outcomes. Yet, as we've seen, challenges often serve as catalysts for innovation. The strategies we've discussed, from adhesion enhancement to controlled drying, particle engineering, and beyond, empower us to confront delamination and cracking head-on. These approaches offer pathways to fortify interfacial bonds, distribute stresses, and enhance the resilience of colloidal films. In closing, while delamination and cracking may present formidable obstacles, they also represent opportunities for progress. As our understanding of these complex phenomena deepens, and as collaboration across disciplines flourishes, we are poised to unlock new horizons in materials design and engineering. With determination and ingenuity, we embark on a journey toward more reliable, durable, and resilient colloidal films, poised to shape the technological landscape of the future and usher in a new era of innovation.

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3rd Year

Investigating Novel Synthesis Methods for Aerogels

Introduction

Aerogels are a remarkable class of materials known for their extraordinary properties and versatile applications in various fields of science and engineering. These lightweight, porous materials are composed of a three-dimensional network of interconnected nanoscale particles, resulting in an extremely low density and high surface area. The name "aerogel" reflects their gel-like composition and the fact that they are predominantly composed of air.

Figure 1 Aerogel

Significance of Aerogels

Aerogels exhibit a range of exceptional properties that make them highly significant in numerous applications. Firstly, their ultralow density allows them to float on air, making them one of the lightest solid materials known to humankind. Secondly, their exceptional thermal insulating properties make them invaluable for applications in aerospace, construction, and energy conservation. Aerogels are also known for their high surface area, which enables them to absorb liquids and gases, making them vital in oil spill cleanup, water purification, and catalysis. Moreover, their transparent nature in some forms makes them suitable for optical and photonic applications, including transparent insulation.

Importance of Investigating Novel Synthesis Methods

The development of novel synthesis methods for aerogels is crucial for several reasons. Firstly, it allows for the tuning of aerogel properties, such as porosity, surface chemistry, and mechanical strength, to suit specific applications. Secondly, novel synthesis methods can enable the production of aerogels at a larger scale and in more cost-effective ways, which is vital for their commercial viability. Additionally, exploring new synthesis routes can lead to the creation of tailored aerogels with enhanced properties, expanding their range of applications.

Traditional Synthesis Methods for Aerogels

a. Sol-Gel Process: The sol-gel process is a widely used traditional method for the synthesis of aerogels. It involves the conversion of a liquid sol (a colloidal suspension of nanoparticles) into a gel, followed by the removal of the liquid phase to form a porous aerogel structure.

In the first step, a precursor solution containing metal alkoxides or other suitable materials is prepared. This solution is then subjected to hydrolysis and polycondensation reactions to form a three-dimensional network of interconnected nanoparticles. The resulting sol gradually transforms into a gel with a solid-like structure.

The critical step in the sol-gel process is the removal of the solvent without collapsing the gel structure. This is typically achieved through supercritical drying or freeze-drying. In supercritical drying, the liquid is replaced with a supercritical fluid (often carbon dioxide) to maintain the gel's porous structure. This process involves carefully controlling temperature and pressure to ensure the preservation of the desired aerogel properties.

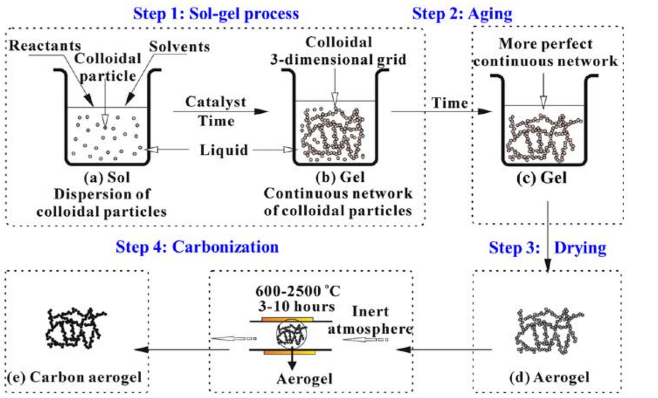

Figure 2 General preparation process of polymer or carbon aerogels.

b. Supercritical Drying Techniques: Supercritical drying techniques are essential in aerogel synthesis, as they prevent the capillary forces that would collapse the delicate gel structure during conventional drying. In supercritical drying, a liquid solvent is replaced with a supercritical fluid (usually supercritical carbon dioxide) while maintaining critical pressure and temperature conditions.

The supercritical fluid possesses gas-like diffusivity and liquid-like density, allowing it to efficiently replace the liquid in the gel without damaging the porous network. The key steps in supercritical drying involve first immersing the gel in the supercritical fluid, allowing it to permeate the gel structure. Then, by slowly depressurizing and heating the system, the supercritical fluid transitions back to its gaseous state, leaving behind the porous aerogel.

Supercritical drying techniques offer precise control over the final aerogel's porosity, surface area, and mechanical properties. They are particularly well-suited for producing high-quality aerogels with tailored properties for applications in thermal insulation, catalysis, and environmental remediation.

Tailoring Properties of Aerogels through Novel Synthesis Methods

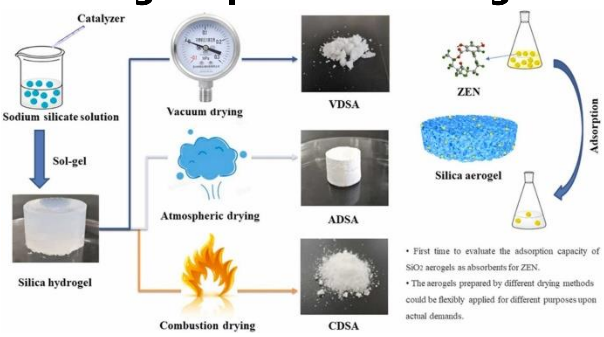

Figure 3 Novel Synthesis of Aerogel

Aerogels, often dubbed as "frozen smoke," are extraordinary materials known for their remarkable properties, including low density, high porosity, and exceptional thermal insulating properties. Tailoring these properties through novel synthesis methods is a fascinating avenue of research within chemical engineering, with promising applications in various industries.

a. **Modifying Precursor Materials:** One approach to customize aerogel properties involves altering the precursor materials. By selecting different chemical precursors, such as silica, carbon, or polymers, engineers can control the chemical composition and resulting properties of the aerogel. For example, incorporating nanoparticles or organic compounds into the precursor mix can enhance mechanical strength, electrical conductivity, or even catalytic activity, depending on the desired application.

b. **Exploring Alternative Solvents:** Another avenue is to explore alternative solvents in the aerogel synthesis process. Traditional aerogel production typically employs supercritical drying techniques with carbon dioxide, but experimenting with different solvents can yield aerogels with distinct properties. By choosing solvents with varying polarities or densities, researchers can achieve tailored pore structures, surface chemistries, and thermal conductivities.

c. **Optimizing Processing Conditions:** Fine-tuning processing conditions during the gelation and drying stages is critical. Parameters like temperature, pressure, and time can significantly impact aerogel morphology and properties. Careful optimization can lead to improved mechanical strength, reduced shrinkage, and enhanced porosity, allowing for targeted applications such as lightweight structural materials, thermal insulation for space exploration, or efficient absorbents for environmental remediation.

Recent Advancements in Novel Synthesis Methods

a. **Template-assisted synthesis:** Template-assisted synthesis has emerged as a groundbreaking approach in chemical engineering, revolutionizing the fabrication of advanced materials with precisely controlled structures. It involves the use of templates, which can be organic or inorganic, to guide the assembly of atoms or molecules into desired configurations. This method allows for the creation of complex materials with tailored properties, such as nano porous zeolites, nanowires, and nanotubes. Researchers have achieved remarkable success in fields like catalysis and energy storage.

b. **Microwave-assisted synthesis:** Microwave-assisted synthesis is a rapid and efficient technique that utilizes microwave radiation to heat reaction mixtures, enabling faster and more precise chemical reactions. This method has gained prominence due to its ability to reduce reaction times, enhance yields, and produce higher-purity products. Microwave heating facilitates uniform and selective heating, reducing unwanted side reactions. It has applications in various domains, including organic synthesis, pharmaceuticals, and nanomaterials fabrication.

c. **Freeze-drying and ambient pressure drying:** Freeze-drying and ambient pressure drying techniques have advanced the production of porous materials, nanoparticles, and pharmaceutical formulations. Freeze-drying involves freezing a solution or suspension and then removing the solvent under reduced pressure, preserving the material's structure and properties. Ambient pressure drying, on the other hand, dries materials without the need for high vacuum, reducing energy consumption. These methods have gained significance in the pharmaceutical industry for drug formulation and the creation of aerogels, which find applications in thermal insulation, catalysis, and environmental remediation.

Characterization Techniques for Aerogels

Aerogels are fascinating materials known for their ultra-lightweight, high porosity, and exceptional insulating properties. To fully understand and utilize their potential, various characterization techniques are employed, including pore size distribution analysis, surface area measurement, and mechanical strength testing.

a. **Pore Size Distribution Analysis:** Characterizing the pore size distribution is crucial for optimizing the performance of aerogels. Techniques such as mercury intrusion porosimeter and nitrogen adsorption/desorption methods are commonly used. Mercury intrusion porosimeter involves subjecting the aerogel to increasing pressure with mercury, allowing measurement of pore size distribution from nanometres to micrometres. Nitrogen adsorption/desorption analyses the isotherms to determine the specific surface area and pore size distribution, with smaller pores corresponding to higher pressures during adsorption. Understanding pore size distribution aids in tailoring aerogels for specific applications like catalysis, filtration, or insulation.

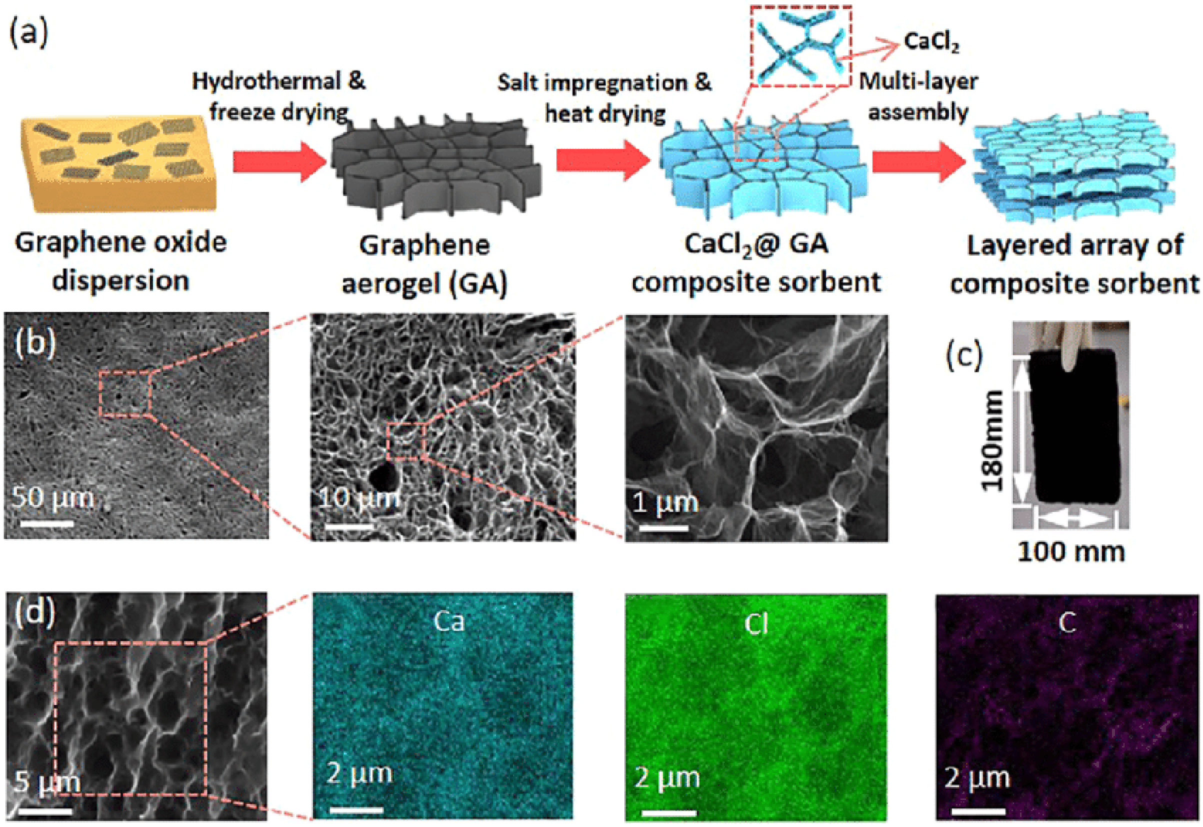

Figure 4 : Synthesis and characterization of graphene aerogel-based composite sorbents

b. **Surface Area Measurement:** The specific surface area of aerogels greatly influences their performance. Braeuer-Emmett-Teller (BET) analysis is a common method to measure surface area. It calculates the area based on gas adsorption onto the aerogel's surface. The high surface area of aerogels makes them excellent candidates for adsorption-based applications, such as environmental remediation or gas storage.

c. **Mechanical Strength Testing:** Assessing the mechanical strength of aerogels is essential for applications requiring load-bearing properties. Techniques like compression testing and nanoindentation evaluate their mechanical behaviour. Aerogels often exhibit brittleness due to their low-density structure, but modifications such as reinforcement with polymers or nanoparticles can enhance their mechanical strength. Understanding the mechanical properties is crucial for applications like lightweight structural components or impact-resistant materials.

Challenges in Investigating Novel Synthesis Methods

Investigating novel synthesis methods in chemical engineering is a complex endeavour laden with challenges. Three critical hurdles in this pursuit are reproducibility and standardization, scale-up and manufacturing, and cost-effectiveness.

Reproducibility and standardization pose a formidable challenge when exploring new synthesis methods. In research, it is essential that results can be replicated reliably. Variations in experimental conditions, raw materials, or instrumentation can lead to inconsistent outcomes, hindering the credibility of the method. Achieving a high degree of reproducibility often demands meticulous documentation, stringent quality control, and rigorous statistical analysis.

Scale-up and manufacturing are another obstacle. What works on a laboratory scale may not be feasible or cost-effective when attempting to produce chemicals or materials at an industrial scale. Engineers must grapple with issues like process optimization, equipment scalability, and safety concerns. The transition from the lab bench to the factory floor necessitates substantial investment, testing, and adaptation.

Cost-effectiveness is a paramount consideration. Developing and implementing a novel synthesis method must make economic sense. Factors such as the cost of raw materials, energy consumption, and waste disposal can significantly impact feasibility. Finding a balance between innovation and affordability is a persistent challenge in chemical engineering.

Future Directions and Potential Applications

Multifunctional Aerogels: Multifunctional aerogels represent a promising avenue for future research and applications in chemical engineering. These highly porous materials, composed of a network of interconnected nanoparticles or nanofibers, exhibit exceptional properties such as low density, high surface area, and excellent thermal insulation. In the coming years, we can expect to see innovative applications of aerogels in various fields.

One potential future direction is in the development of multifunctional aerogels for advanced insulation in buildings and industrial processes. These aerogels can significantly improve energy efficiency by providing superior thermal insulation, reducing energy consumption, and lowering greenhouse gas emissions.

Additionally, aerogels hold promise in the aerospace industry as lightweight materials for spacecraft and aircraft insulation, enhancing fuel efficiency and reducing emissions.

Energy Storage Applications: The future of energy storage lies in the development of advanced materials and systems, and chemical engineers are at the forefront of these innovations. Novel materials like supercapacitors and advanced battery technologies, such as solid-state batteries, are expected to play a pivotal role in addressing energy storage challenges.

Chemical engineers are actively researching and designing materials that can store energy more efficiently and sustainably. These advancements will have a significant impact on the widespread adoption of renewable energy sources, enabling grid stabilization, load balancing, and uninterrupted power supply.

Catalysis and Environmental Remediation: The field of catalysis continues to evolve, with a focus on green and sustainable processes. In the future, we can anticipate the development of more efficient catalytic materials and processes for chemical transformations, including the conversion of greenhouse gases into valuable products.

Catalysis will also play a vital role in environmental remediation. Chemical engineers will explore innovative catalytic technologies to purify air and water, remove pollutants, and mitigate the impact of industrial emissions on the environment.

Conclusion

In conclusion, the pursuit of novel synthesis methods in Chemical Engineering holds immense significance. Firstly, it addresses the ever-evolving challenges in the field, such as the need for more sustainable and efficient processes. Investigating new synthesis techniques can lead to breakthroughs in resource utilization, waste reduction, and energy efficiency. Moreover, it allows for the creation of advanced materials with tailored properties, fostering innovation in industries ranging from pharmaceuticals to materials science.

The potential impact on the field of Chemical Engineering cannot be overstated. The development of novel synthesis methods has the potential to revolutionize manufacturing processes, making them more environmentally friendly and cost-effective. It can lead to the discovery of entirely new materials with applications that we can't even foresee yet. This innovation can enhance the competitiveness of industries, drive economic growth, and address pressing global challenges, such as climate change and resource scarcity.

However, it's essential to acknowledge that our understanding of synthesis methods is far from complete. Thus, a call for further research and exploration is imperative. Continued investigation into novel synthesis methods is necessary to unlock their full potential. This entails interdisciplinary collaboration, cutting-edge research techniques, and the integration of emerging technologies. It also requires a commitment to ethical and sustainable practices to ensure that the benefits of novel synthesis methods are maximized while minimizing their environmental and social impacts.

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TECHNICAL ESSAYS FROM CHEMSPARK'23

Environment and Pollution control

Introduction:

Environment and pollution control call an attention to the actions and policies that aim to protect and sustain the natural environment and attenuate the worst effects of human activities on it. This involves the management of various forms of pollution such as soil pollution, air pollution and water pollution and along with that, the conservation of biodiversity, protection of natural resources, and lowering of greenhouse gas emissions.

Effective environment and pollution control recommends a well-rounded approach, which includes individuals, communities, industries, and government. Individuals can contribute to this endeavor by acquiring sustainable actions such as reducing their carbon footprint, recycling waste, and preserving natural resources. Communities can implement local initiatives such as planting trees, promoting public transportation, and controlling garbage disposal.

Industries plays a big role in this evaluation by adopting cleaner production techniques, using renewable energy sources, and executing accountable waste management practices. Government can enforce their rules, regulations and policies to ensure that the industries act in accordance with environmental standards and impose penalties for non-compliance. Moreover, government can support R&D of sustainable technologies and provide funding for programs of environmental protection.

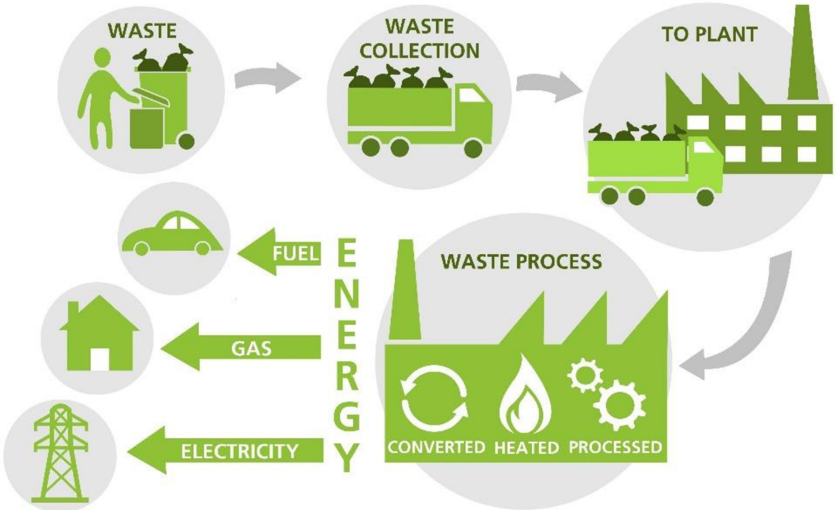
Environment and pollution control is necessary to ensure the well-being of our earth's environment and future generations. It is an essential responsibility that requires collaboration and concerted efforts from all the associators.

Relevance under current scenario:

~~The relevance of environment and po~~llution control in the current scenario is becoming gradually important due to the increasing recognition of the influence of human activities on the environment and the resulting warning to our well-being and the sustainability of our planet earth.

For instance, climate change has become a hectic problem, with rising temperatures causing extreme weather hazards such as heatwaves, droughts, and floods and also significant impacts on biodiversity and human health. On the other hand, air pollution is a major environmental threat, causing respiratory disease and premature deaths and damaging human productivity and economic growth.

Figure 1: Steps of environment and pollution control



Water scarcity is also becoming a major concern, specially in the areas facing drought and population growth, leading to food insecurity, conflicts, and displacement of people. Biodiversity reduction is another biggest challenge, which has significant inference for the sustainability of our planet, including the provision of ecosystem services such as food production, pollination and water filtration.

To address these challenges, environment and pollution control measures are very much important. This needs an effective action from individuals, businesses, communities and government also. Overall, the relevance of environment and pollution control in the current scenario is critical to avert the worst effects of human activities on the environment and promote sustainable development.

Economic viability:

The economic viability of environment and pollution control is a topic of argument, with some arguing that environmental protection and pollution control estimates impose significant costs on businesses and economy, while others support that investing in these measures can accelerate economic growths and benefits in the long run.

Moreover, applying environment and pollution control measures multiplies the costs of production for businesses. For example, businesses may need to invest in more effective cleaner technologies, which can be more expensive. Additionally, adherence with environmental rules and regulations may require additional resources such as personnel, monitoring and reporting.

However, there is also a conformation to suggest that investing in environment and pollution control estimates can lead to long-term economic benefits. For example, reducing air pollution increases significant savings in healthcare costs and increase productivity, as employees are less favorable to get sick. Moreover, investing in renewable energy resources can reduce dependency on fossil fuels and balance energy prices, leading to greater energy security and economic stability. Moreover, there are some important economic opportunities in the evolution and distribution of clean technologies. The renewable energy sector is growing rapidly day by day and many businesses are investing in R&D wing to develop cleaner production techniques and reduce waste. By investing in these sectors, businesses can strengthen themselves to take advantage of the competitive growing market and contribute to job creation and economic growth.

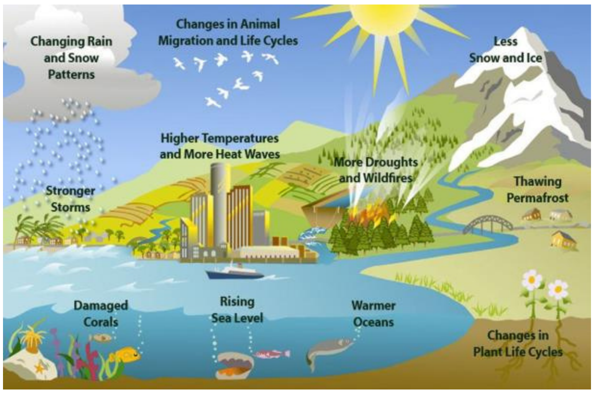
Additionally, there is growing identification that environmental protection and economic growth are not mutually exclusive goals. Sustainable development leads to promote economic growth while protecting the natural environment and investing in environment and pollution control measures can be an essential part of this approach.

The economic viability of environment and pollution control is a complex matter and the costs and benefits of these measures will rely on the specific context and circumstances. However, there is evidence to suggest that investing in environment and pollution control measures can lead to long-term economic benefits and contribute to sustainable economic growth. So, it is crucial to view that environment and pollution control measures as an investment in the future rather than a cost to be borne in the present.

Impact on environment:

Environment and pollution control estimates can have a strong impact on the environment by reducing pollution levels, protecting natural resources and advancing sustainable development.

One of the most critical effects of environment and pollution control measure is decreasing pollution levels in the air, water and soil. For example, air pollution control measures such as implementation of emission standards for vehicles and industries, usage of cleaner fuels and promotion of public transportation can



decrease the release of dangerous pollutants such as carbon monoxide, nitrogen oxides and particulate matter. This can effectively improve air quality, reduce respiratory diseases and improve the quality of life for people.

Figure 2: Natural resources- types and importance

Water pollution control measures such as accomplishing waste water treatment systems, imposing regulations for discharge limits and promoting sustainable agriculture actions can reduce the emission of harmful pollutants such as nutrients, chemicals and microorganisms into water bodies. This can enhance water quality, preserve aquatic ecosystems and protect public health.

Environment and pollution control measures can also help protect natural resources such as forests, wildlife and marine ecosystems. For example, furnishing sustainable forestry practices such as reforestation and reducing deforestation can help to mitigate climate change, improve soil quality and protect biodiversity. Preserving wildlife habitats can also promote ecological resilience and gives valuable ecosystem services such as pollination and seed dispersal.

Environment and pollution control estimates can promote sustainable development by reducing the worst impacts of economic activities on the environment. For instance, promoting sustainable tourism, eco-tourism and advance green technologies can reduce greenhouse gas emissions, minimize waste production and promote the circular economy. It can create new business opportunities, generate employment and lead to an economic growth while minimizing the negative effects on the environment.

Conclusion:

In conclusion, environment and pollution control are critical aspects that are important for sustainable development and the well-being of living organisms.

Effective measures such as reducing carbon footprint, promoting sustainable agriculture, adopting clean energy, implementing responsible waste management practices and acquiring new advanced green technologies can mitigate environmental deterioration and promote sustainable development. By taking suitable action, we can ensure the sustainability of our planet earth and protect the well-being of current and future generations. We must acknowledge the importance of environment and pollution control and take an immediate action to reduce environmental degradation. This requires a collective effort from individuals, businesses and governments at all levels. By working together, we can ensure a sustainable future for all.

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Mercury Contamination Prevention and Control

Introduction:

Mercury is a liquid heavy metal that is used in many industries. It is also found in effluents of some industries. Ideally, mercury should be eliminated from industrial effluents, but it is easier said than done. Mercury is an important component of

alloy
making. Mercury is alloyed with other metals to form amalgams. Mercury is used in electrical and electronic industries, medical equipment industries, paper manufacturing and paint industries. Mercury remains in the nature, either in elemental form or as compounds. Almost all mercury compounds cause neurotoxicity. Once released into the environment, mercury compounds biomagnifies and bioaccumulates in organisms. When humans consume these organisms, they suffer from mercury poisoning, hence mercury pollution not only affects our ecosystem, it also us. Not only that, but mercury is also carcinogenic, exposure to mercury for a long time increases the chance of cancer. Although elemental mercury is not considered a human carcinogen, its compounds like mercuric chloride and methyl mercury are different case. Mercury vapour is an air pollutant as well, resulting from the burning of fossil fuels and mining of minerals.

Relevance under current scenario:

Mercury and its compounds can be considered as pollutants even in small amounts. A famous case of mercury poisoning is the one involving an internationally known research chemist Karen Wetterhahn. She was experimenting with dimethylmercury and was wearing all the protective equipment necessary. Even then, it took just two drops of dimethylmercury falling on her glove to kill her. Her death was not a quick one, she slowly became psychotic, had difficulties with speech and balance, and died of organ failure. This shows how even a small amount of mercury can be toxic.

About 3 million people in the world have fish or some kind of wild caught seafood in their diet. Biomagnification and bioaccumulation of mercury in seafood can affect this population adversely, putting them at a higher risk of mercury poisoning and cancer. Most methods of separation of mercury compounds are cost intensive and the economical way of separation i.e., chemical precipitation produces a semi solid sludge contaminated with mercury which has its own set of problems regarding disposal. Hence, it is quite possible for industries to cut corners when it comes to managing mercury waste.

Economic viability:

Economically speaking, separating mercury is a difficult job, but not an impossible one. It takes about 2.5 to 3 lakhs to set up a wastewater treatment plant of 8 to 10 KLD. Running and maintaining it costs even more. However, as a wise man once said, actions have consequences. The monetary amount is just a consequence of trying to do our part in saving the environment and human life. If we were to do nothing, and let all the mercury contaminated waste into the environment then the monetary cost would be higher. The worst affected would be the population living along the coasts and rivers, since they depend on seafood for both consumption and livelihood. There will be an increased risk of cancer and neurological deficits. Death rate will skyrocket and public healthcare system will be overrun. The cost of that will be significantly higher than just cleaning up our industrial wastes. Actions have consequences, but inaction has its own consequences too, which one is greater is evident.

Impact on the environment:

Cleaning up and dealing with mercuric waste is certainly beneficial for the environment. Mercury pollution in water causes death of aquatic wildlife and disruption of the aquatic ecosystem. Those organisms that do not die end up on our plates, and poison us. Mercury poisoning on a large-scale can disrupt our healthcare system and cause mass hysteria and distress. Mercury pollution of soil causes stunted crop growth and decreased yield. It can disrupt terrestrial ecosystem as well by biomagnifying and bioaccumulating in the food chain. This way once again mercury can affect human population by contaminating food produce. Loss of mercury will result in increased mining activity to mine more mercury ores, which is detrimental to the environment as well. All of this can be prevented with proper effluent treatment and vigilant disposal of mercury contaminated waste. Cases like Minamata Bay disaster occurs mainly due to human greed and for cutting costs. If we extract mercury from the waste then the need for unnecessary mining will vanish and our environment will be benefited.

Conclusion:

All of the above points are slight exaggeration of the reality and possible realities that could have happened if things went wrong. In reality, adequate number of precautions and vigilance is maintained to prevent mercury pollution from happening in a large scale. However, there is no minimum dose of toxicity for heavy metals like mercury and lead. In any amount, mercury can show signs like early onset of neurological aging, increased risk of motor function deficit and stupor. Invention of tetraethyllead and its incorporation in petrol though out the generations have already lowered the average IQ of the human civilization by 3 points, let us not repeat the same mistake with mercury. This shiny and beautiful liquid metal is indeed toxic and should be dealt with utmost vigilance and caution.

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RENEWABLE ENERGY AND CLEAN FUEL TECHNOLOGY

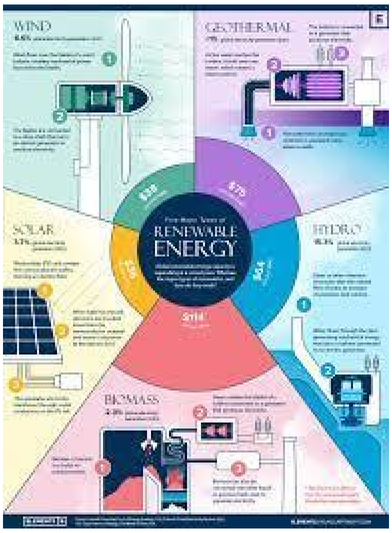
INTRODUCTION

Renewable energy refers to energy sources that are replenished naturally and continuously, such as solar, wind, geothermal, hydropower, and biomass. These sources of energy are considered "renewable" because they are sustainable and will not run out like fossil fuels. Clean fuel technology, on the other hand, refers to technologies that reduce or eliminate harmful emissions from traditional fuels, such as gasoline or diesel.

Renewable energy technologies are becoming increasingly popular as concerns

about

climate change and the environmental impact of fossil fuels grow. Solar panels and wind turbines are examples of renewable energy technologies that have become more affordable and accessible in recent years.



Geothermal energy, which involves harnessing heat from the earth's core, is also gaining traction as a renewable energy source.

Clean fuel technologies are also becoming more common as governments and individuals seek to reduce their carbon footprint. Electric vehicles, which run on batteries instead of gasoline or diesel, are a popular example of clean fuel technology. Hydrogen fuel cells, which convert hydrogen gas into electricity, are also being developed as a cleaner alternative to fossil fuels.

Overall, renewable energy and clean fuel technologies are important tools in the

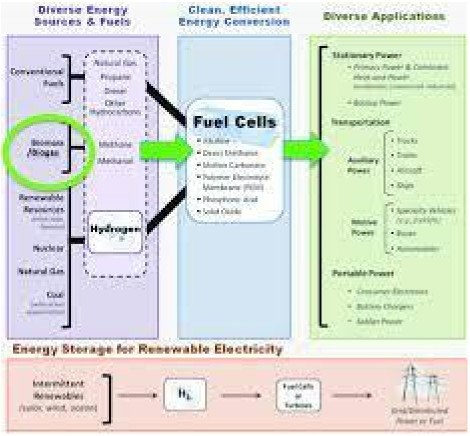
fight

against climate change and the move towards a more sustainable future.

RELEVANCE UNDER CURRENT SCENARIO

Renewable energy and clean fuel technology are more relevant than ever in the current scenario as the world faces the challenges of climate change, increasing global temperatures, and the need for a transition to a low-carbon economy.

The use of renewable energy sources has become a critical part of efforts to reduce greenhouse gas emissions and mitigate climate change. In many countries, policies and regulations are being put in place to promote the use of renewable energy sources and encourage the development of clean fuel technologies. For example, the Paris Agreement, which was signed by 195 countries, aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels, and calls for a transition to clean energy sources.



Renewable energy and clean fuel technologies also offer significant economic benefits. The cost of renewable energy sources such as solar and wind power has been decreasing rapidly, making them increasingly competitive with traditional fossil fuels. In addition, the development and deployment of clean fuel technologies create new job opportunities and drive innovation.

Moreover, the current global health crisis caused by the COVID-19 pandemic has highlighted the importance of reducing air pollution and improving public health. Renewable energy and clean fuel technologies offer solutions to reduce air pollution and improve public health, as they produce little to no harmful emissions.

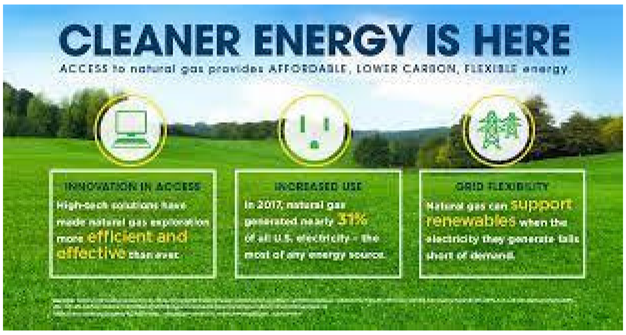
Overall, renewable energy and clean fuel technologies are critical components of efforts to mitigate climate change, reduce air pollution, and create a more sustainable and resilient future for all.

ECONOMIC VIABILITY

The economic viability of renewable energy and clean fuel technology has been improving significantly in recent years, as these technologies become more efficient and cost-effective.

The cost of renewable energy sources such as solar and wind power has been decreasing rapidly, making them increasingly competitive with traditional fossil fuels. According to the International Renewable Energy Agency (IRENA), the cost of renewable energy technologies has decreased significantly in the past decade, and renewable energy is now often the cheapest source of electricity in many parts of the world.

In addition, clean fuel technologies such as electric vehicles (EVs) are becoming more affordable, with the cost of EV batteries declining by over 80% in the past decade. The cost of producing hydrogen fuel cells, which are another form of clean fuel technology, is also decreasing rapidly.



Furthermore, the economic benefits of renewable energy and clean fuel technologies extend beyond cost savings. These technologies can create new job opportunities and drive innovation, which can contribute to economic growth and development. For example, a report by IRENA found that the renewable energy sector employed over 11 million people worldwide in 2018, and this number is expected to continue growing.

Moreover, the transition to renewable energy and clean fuel technologies can also help countries reduce their dependence on fossil fuel imports, which can improve energy security and reduce vulnerability to fluctuations in fossil fuel prices.

Overall, the economic viability of renewable energy and clean fuel technology is becoming increasingly apparent, as these technologies become more efficient, cost-effective, and provide broader economic benefits.

IMPACT ON ENVIRONMENT

Renewable energy and clean fuel technology have a significantly lower impact on the environment compared to traditional fossil fuel sources. However, like any form of energy production, they do have some environmental impacts that need to be considered.

Renewable energy sources such as solar, wind, and hydropower do not produce greenhouse gas emissions or air pollutants during operation, which reduces their impact on climate change and air quality. However, the manufacturing and disposal of the materials used to produce these technologies, such as solar panels and wind turbines, can have environmental impacts, particularly if not properly managed. For example, the production of solar panels involves the use of toxic chemicals, and improper disposal of these materials can result in water and soil contamination.

Similarly, clean fuel technologies such as electric vehicles (EVs) produce no tailpipe emissions during operation, which can significantly reduce air pollution in urban areas. However, the production of EV batteries involves the extraction of raw materials such as lithium and cobalt, which can have environmental impacts if not responsibly managed.

Hydrogen fuel cells, another form of clean fuel technology, produce only water as a byproduct. However, the production of hydrogen can be energy-intensive and may rely on the use of fossil fuels, which can lead to greenhouse gas emissions.

In conclusion, renewable energy and clean fuel technologies have a lower impact

on

the environment compared to traditional fossil fuel sources. However, the environmental impacts of these technologies need to be carefully considered throughout their life cycle, including their manufacturing, use, and disposal, to ensure that they are truly sustainable and have minimal negative impact on the environment.

CONCLUSION

In conclusion, renewable energy and clean fuel technologies have the potential to play a significant role in mitigating climate change, improving air quality, and creating a more sustainable and resilient future for all. These technologies offer significant economic, social, and environmental benefits, and their importance is becoming increasingly apparent. However, their environmental impacts need to be carefully considered and managed throughout their life cycle to ensure that they are truly sustainable and have minimal negative impact on the environment. The development and deployment of renewable energy and clean fuel technologies require collaboration and commitment from governments, industry, and society as a whole, and the transition to a low-carbon economy will be a key challenge and opportunity for the decades to come.

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An Investigation into the Synthesis, Properties, and Applications of Covalent Organic Frameworks (COFs) for use in Sustainable Technologies

1. Introduction:

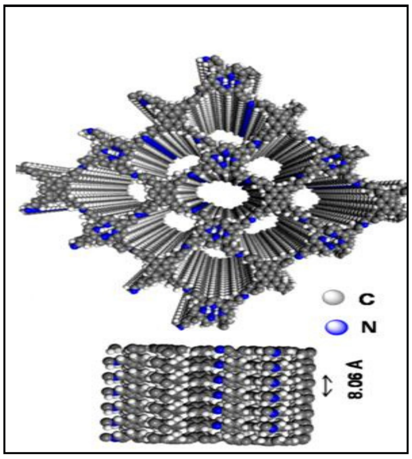

Figure 1: SB-PORPy-COF, prepared by Solvothermal Synthesis using 5,10,15,20-Tetrakis(4-aminophenyl) porphyrin, 1,3,6,8-tetrakis(4-formylphenyl) pyrene, an acetic-acid catalyst (6 M), o-dichlorobenzene, and dimethylacetamide. (Doi:10.1021/acsami.7b06968)

Covalent Organic Frameworks (COFs) are a class of porous materials that have gained significant attention in recent years due to their potential for various applications, including gas storage, catalysis, and sensing.

COFs are made up of organic building blocks that are linked together through covalent bonds to form a crystalline structure. These materials are unique in that they have a high degree of crystallinity, high surface area, and tuneable properties.

The history of COFs (covalent organic frameworks) can be traced back to the 1990s when researchers began exploring ways to synthesize 3D porous materials using covalent bonds. The first successful synthesis of a COF was reported in 2005 by Yaghi and colleagues, who used reticular chemistry to synthesize a two-dimensional (2D) COF using boronic acid and cyanuric chloride building blocks.

In the following years, many other COFs were synthesized using different building blocks and synthetic strategies. In 2007, the first 3D COF was reported by Yaghi and colleagues, which was based on triphenylamine and triformylphloroglucinol building blocks. In 2010, Ding and co-workers reported the synthesis of a mesoporous COF using a dual-template approach.

Since then, COFs have become a rapidly growing field of research with numerous applications in gas storage, catalysis, sensing, and optoelectronics. The field has seen a surge of interest in recent years, and many new COFs with unique properties have been synthesized using a variety of building blocks and synthetic strategies.

2. Types of Materials in COFs:

The building blocks used in COFs are typically organic molecules which are chosen based on their ability to form strong and stable covalent bonds and their potential for pore formation. Some examples of commonly used building blocks include:

1. Aromatic compounds: Aromatic compounds such as benzene, naphthalene, and anthracene are commonly used as building blocks due to their high stability and ability to form strong covalent bonds.

2. Heterocycles: Heterocycles such as pyridine, pyrazine, and triazine are often used as building blocks due to their ability to form nitrogen-rich materials, which have potential for applications such as gas separation and catalysis.

3. Polycyclic compounds: Polycyclic compounds such as coronene and hexabenzocoronene are used as building blocks to form COFs with extended pi-conjugation, which have potential for applications in electronics and photonics.

3. Structure of COFs:

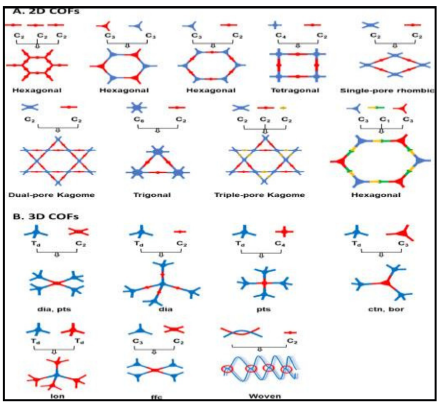

Figure 2: Topology diagrams representing a general basis for COF design and construction of (A) 2D COFs and (B) 3D COFs. (https://doi.org/10.1016/j.giant.2021.100054)

The structure of COFs can be categorized into two types: 2D and 3D.

1. 2D COFs: 2D COFs are composed of layers of organic building blocks that are stacked on top of each other through weak intermolecular forces such as van der Waals forces. The layers can be separated through chemical or physical methods to create free-standing sheets. The most commonly used building blocks for 2D COFs are imine-based linkers, which form strong covalent bonds and can be easily synthesized.

2. 3D COFs: 3D COFs are composed of three-dimensional frameworks of organic building blocks that are linked together through covalent bonds to form a porous structure. The most commonly used building blocks for 3D COFs are triazine-based linkers, which have a high degree of symmetry and can form highly ordered structures.

Two-dimensional (2D) COFs exhibit greater promise than three-dimensional (3D) COFs owing to two key factors. The first factor is attributed to the inherent stacking between adjacent layers, resulting in π-π interactions. This stacking phenomenon enhances the charge carrier mobility of 2D COFs through the multi-stacked columnar channels, thereby exhibiting promising optoelectronic, conductivity, and electroactivity properties.

5. Synthesis Methods of COFs:

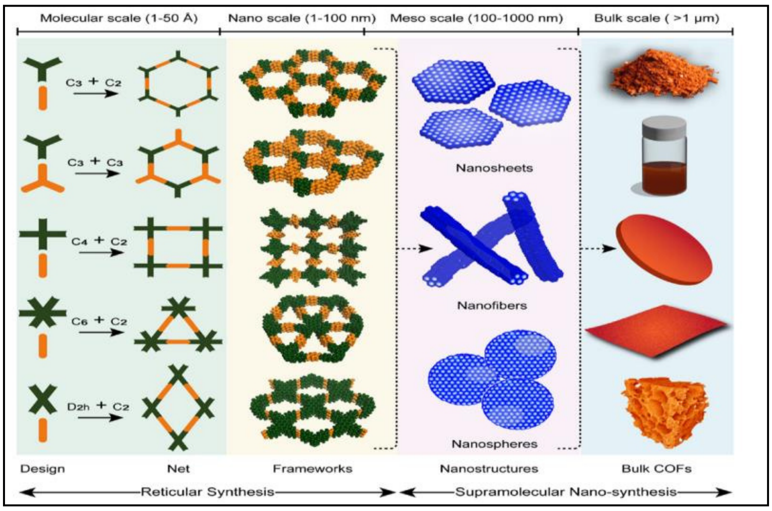

Figure 3: Schematic showing conceptualization of COFs from the molecular scale to the bulk scale. Reticular design of COFs from net to framework. Transformation of nanostructures to bulk COFs coined as the supramolecular nano synthesis. (doi:10.1021/acsnano.1c05194)

There are several synthesis methods that are used to prepare COFs, which can be broadly classified into two categories principally: solvothermal and mechanochemical methods.

5.1 Solvothermal Synthesis:

Solvothermal methods involve the reaction of organic building blocks with a solvent at high temperatures and pressures to promote the formation of covalent bonds. The most commonly used solvents for solvothermal synthesis are DMF, DMSO, and NMP.

Method:

1. Selection of building blocks: The choice of organic building blocks is crucial in determining the final properties of the COF. The building blocks should be chosen based on the desired properties of the COF.

2. Preparation of the solvent: The solvent(s) for the reaction should be chosen based on the solubility of the building blocks and the desired properties of the COF. The solvent should also be able to withstand high temperature and pressure.

3. Mixing of building blocks and solvent: The building blocks are mixed with the solvent(s) in a reactor vessel. The mixture is then stirred to ensure the building blocks are well dispersed in the solvent.

4. Heating under pressure: The reactor vessel is heated under pressure to induce the reaction between the building blocks. The reaction temperature and time will depend on the building blocks and solvent used.

5. Cooling and washing: Once the reaction is complete, the mixture is cooled to room temperature and the COF is washed with a suitable solvent to remove any unreacted building blocks and impurities.

6. Post-processing: The washed COF is then dried in an oven or vacuum desiccator to remove any remaining solvent. The COF can also be subjected to further post-processing steps such as activation, functionalization, or modification to enhance its properties.

Advantages of solvothermal synthesis of COFs include high crystallinity and controlled growth, and scalability for large-scale production. Disadvantages include solvent dependence, limiting applications due to toxicity or flammability, and long reaction times that can be a disadvantage for industrial-scale production.

Some examples of COFs synthesized by solvothermal methods:

1. TPB-COF: This is a porous COF synthesized using 1,3,5-triformylphloroglucinol (TFP) and 1,3,5-tris(4-aminophenyl) benzene (TPB) via solvothermal synthesis. The material has high surface area, high thermal stability, and good adsorption properties.
2. PAF-1: This is a COF synthesized using 1,3,5-tris(4-aminophenyl) benzene (TPB) and terephthaldehyde (TPA) via solvothermal synthesis. The material has high surface area, high porosity, and good stability in various solvents.

5.2 Mechanochemical Synthesis

Mechanochemical synthesis of COFs involves the use of high-energy milling to generate mechanical force to initiate chemical reactions between building blocks. The method is a rapid, efficient, and green approach to the synthesis of COFs and requires minimal solvent use.

Mechanochemical methods involve the grinding or milling of solid reactants in the presence of a catalyst or solvent to promote the formation of covalent bonds. The most commonly used catalysts for mechanochemical synthesis are metal salts, such as copper acetate and iron (III) chloride.

Method:

1. Preparation of the building blocks: The starting building blocks are mixed in stoichiometric amounts in a mortar or ball mill. The building blocks can be functionalized with various functional groups to improve the COF properties.

2. Milling: The mixture of building blocks is subjected to high-energy milling in a ball mill for a specified time under controlled conditions of speed and temperature. The mechanical force generated by the milling process initiates the chemical reaction between the building blocks leading to the formation of the COF.

3. Post-synthesis treatment: The obtained COF is usually subjected to post-synthesis treatment to remove any unreacted building blocks, impurities, and milling media. The post-treatment can be carried out by washing the COF with a suitable solvent or using Soxhlet extraction. The COF is then dried under vacuum or in an oven.

Some examples of COFs synthesized by mechanochemical methods:

1. TpPa-1: This COF is composed of triphenylene-based building blocks and was synthesized by grinding the building blocks with potassium hydroxide in a ball mill for 20 minutes.

2. COF-320: This COF is composed of tetraphenyl ethylene-based building blocks and was synthesized by grinding the building blocks with tetrabutylammonium hydroxide in a planetary ball mill for 20 minutes.

Advantages of Mechanochemical Synthesis of COFs include being solvent-free, fast, and producing high purity COFs. However, the method may result in COFs with lower crystallinity and requires specialized equipment that can be expensive and difficult to obtain.

6. Relevance Under the Current Scenario:

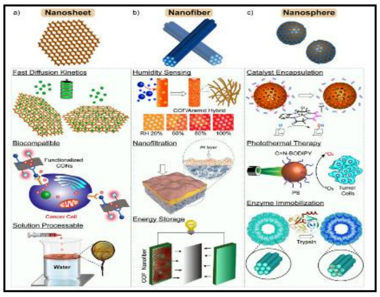

Figure 4: Various Properties and Applications COF nanostructures (doi:10.1021/acsnano.1c05194)

COFs are a promising class of materials due to their unique properties, such as high surface area, ordered pore structure, and tuneable properties, making them suitable for various applications in industries such as energy, environmental, and biomedical sectors.

• Energy Conversion: COFs can be used as catalysts in energy conversion reactions, such as CO2 reduction and water splitting, which are essential for the development of renewable energy technologies. COFs have shown promising results in photocatalysis for hydrogen evolution reactions and have also been used as photoanodes in dye-sensitized solar cells.

• Environmental Remediation: COFs can be used for the removal of pollutants from water and air, making them suitable for environmental remediation applications. COFs have been used in the removal of heavy metals, dyes, and organic pollutants from water, and as photocatalysts for the degradation of organic pollutants in air.

• Gas Storage and Separation: COFs can be used for gas storage and separation applications due to their high porosity and surface area. COFs have shown promise in the storage and separation of gases such as hydrogen, methane, and carbon dioxide, which are essential for energy and environmental applications.

• Sensing: COFs can be used as sensors for the detection of various analytes, such as gases, biomolecules, and metal ions. COFs have shown high sensitivity and selectivity in the detection of gases such as ammonia and carbon monoxide, as well as metal ions such as copper and lead.

• Optoelectronics: COFs have shown promise in optoelectronic applications such as light-emitting diodes, photovoltaic devices, and sensors. COFs have been used as luminescent materials for the detection of metal ions and as light-harvesting materials in organic solar cells.

• Biomedicines: COFs hold exceptional promise in biomedicine, with properties such as large surface areas, biodegradability, biocompatibility, and amenability to functionalization making them especially suitable for cell- or tissue-specific targeted drug delivery, transport of drugs across barriers, delivery to intracellular sites, and visualization of drug delivery sites, including theragnostics.

7. Economic viability:

COFs are economically viable due to their low cost of production and the use of abundant and renewable resources. The synthesis of COFs can be achieved using various methods such as solvothermal and mechanochemical methods, which offer different advantages and limitations. For instance, the solvothermal method is suitable for synthesizing large quantities of COFs with high purity, while the mechanochemical method is suitable for producing COFs on a small scale with high crystallinity. The use of low-cost building blocks such as boronic acid, aldehyde, and amine also contributes to the economic viability of COFs. Additionally, COFs have the potential for various applications in gas storage and separation, catalysis, sensing, and optoelectronics, making them suitable for a wide range of industries, including energy, environmental, and biomedical sectors.

8. Impact on Environment:

COFs be used to implement several positive impacts on the environment including:

1. Potential for energy conversion: COFs can be used as catalysts in various reactions that are crucial for the development of renewable energy

technologies. For example, COFs can be used in CO_2 reduction and water splitting reactions, which are essential for the production of sustainable fuels.

2. Environmental remediation: COFs have the potential to remove pollutants from water and air, making them suitable for environmental remediation applications. They can be used for the removal of heavy metals, dyes, and organic pollutants from wastewater, and for the removal of volatile organic compounds and other harmful gases from the atmosphere.

3. Use of renewable resources: The use of abundant and renewable resources, such as water and organic compounds, in the synthesis of COFs reduces their environmental impact. This also makes the synthesis of COFs more sustainable compared to traditional materials, which often rely on non-renewable resources.

4. Reduced waste and emissions: The synthesis of COFs is often done using green chemistry principles, which aim to minimize waste and reduce emissions. This can lead to a reduction in the environmental impact of COFs, making them a more sustainable alternative to traditional materials.

Overall, the potential applications of COFs in energy conversion and environmental remediation, combined with their use of renewable resources and adherence to green chemistry principles, make them an important tool for sustainable development and environmental protection.

9. Conclusion:

COFs are a type of crystalline 2D or 3D porous organic framework (POF) that belong to the POF family of supramolecular structures. They share some characteristics with their nanomaterial cousins. Chief among these relatives are the 2D nanomaterials, which are mainly inspired by graphene and its high surface area, high electron mobility, and high thermal conductivity. They are characterized by a well-defined pore aperture, ordered channel structure, large surface area, and low density. COFs offer desirable properties such as porosity, crystallinity, stability, mechanical strength, and a wide band gap. They can be created using a variety of covalent bonds, including boron ester B-O bonds, Schiff base C=N bonds, B-N bonds, N-N bonds, B-Si-O bonds, and C-C irreversible linkage.

COFs have potential for various applications such as drug delivery, gas storage and separation, catalysis, sensing, and optoelectronics. They are also useful for environmental remediation applications due to their photocatalytic effect. COFs are biocompatible and can be functionalized with nucleic acids for imaging or incorporated into quantum dots for fluorescence quenching. With their unique properties and potential for customization, COFs are a promising class of materials for sustainable technologies in various industries.

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Effective waste management of plastic pollutants

1.Introduction:
The word plastic comes from the Greek term 'plastikos', which means that it can remain shaped in various systems. Plastics consist of long-chain polymer molecules and are extracted from petroleum, coal, and natural gas as its by-product. About 22-43% of plastic wastes end up as landfills, causing the soil to lose its fertility. This is because most of the plastic wastes are nonbiodegradable, contain lethal additives, and can take up to 500 years to decompose. Research indicates that tons of 'microplastic' debris pollute the world's oceans. The consumption of plastic is increasing by 5% every year, and global production is about 150 million tons annually. Chemicals affect people and ecosystems because they are present in the form of plastic wastes. Plastic wastes can appeal to contaminants, including persistent organic pollutants. In the marine context, this is the case because many of these contaminants are hydrophobic and are suitable to contaminate the marine life, especially when buried/disposed of in the sea level. Plastics are not inert but contain several toxic chemicals and are also able to disperse in the form of microplastic contaminants. They contain chemicals that cause chronic respiratory disorders and other health problems. The dioxins released from plastic polymers are fatal organic pollutants that cause cancer and neurological damage and impair the development of reproductive systems. In comparison with other materials, plastics have significant advantages in aspects of weight, durability, and low cost in terms of manufacture. Most plastics manufactured today are nondegradable, finding applications in medical, domestic, and commercial purposes.
Biodegradable plastics are plastics that decompose because of the activity of microbes such as bacteria and algae. Aromatic polyesters are most susceptible to microbial attacks, while aliphatic polyesters are biodegradable owing to their possibly hydrolyzable ester bonds. Some biodegradable plastics may degrade to the extent that the microorganisms can metabolize them entirely into carbon and water. Conventional plastics are often mixed with organic wastes and liquids, rendering them to be hard and impractical to recycle the polymer without the involvement of expensive treatment processes. Recyclable papers are found to be

a potential strategy for the rehabilitation of large quantities of wastes by composting mixed organic food waste scraps and yard trimmings.

2. Relevance under current scenario:

As per the report of worldwide pollution control association, 5 trillion plastic bags are used every year. It is believed that the annual accumulation of plastic waste in seas and oceans is estimated at around 13 million tons. Among all countries, India consumes 50% of single use plastics. In every household, plastic wastes account for more than 10% of the total wastes that are produced every day. India's annual plastic manufacture growth is nearly 16%, compared with China (10%) and the UK (2.5%). Plastics were not regarded as a significant risk, and they were simply regarded as an esthetic interference. The importance of legislating the use of plastics is due to the reasons that they affect soil and marine habitats. Plastics tend to undergo photo-oxidation processes when they are subjected to sunlight or UV radiation. Most often, toxic gases that contain dioxins, furans, and polychlorinated biphenyls are released into the atmosphere. Besides, plastic wastes that are dumped into the landfill lead to soil decay and increase the danger of plastic consumption by domestic animals. Plastics that are disposed of in the aquatic environment result in extinction of aquatic creatures and the danger of biomagnification and bio-amplification because of toxic compounds. Recyclable plastics and biodegradation methods have received attention in recent years because of the increased pressure from environmentalists to reduce environmental dumping. However, not all disposed plastics are suitable for recycling, including plastic bags, packaging wastes, or metalized packaging wastes. This is due to the recalcitrant nature of the disposal product in the low-lying areas, and hence, the landfills that carry plastic wastes pose a risk to the ecosystem.

3. Economic viability:

Plastics are becoming a part of everyone's life and are used every day. Reduce, reuse, and recycle are keywords for the control and management of any pollutants, and this scenario is also applicable to plastics. However, very few plastic products wind up only in a disposal flow owing to its single usage. Reusing of plastics is better than regeneration because they cause less pollution and are less toxic. In recent years, the recycling of plastics has increased significantly. An extensive diversity range of products are being developed and packaged in the after-use plastics such as accessories and toys that can be used in everyday life. It is estimated that 65%-70% of plastics produced end up as waste disposals. A related estimate is that only 25% of plastic beverage bottles are recycled. According to a packaging expert Sterling Anthony, the advancements in technology will expand the plastic recycling infrastructure by making it more efficient and cost-effective.

4. Impact on Environment:

Humans tend to face risks from plastic polymers, especially when they are mixed with additives. Besides, burning of poly- (vinyl chloride) releases halogens that contaminate the air. Plastic additives produce dioxins or toxic substances. Most plastic wastes are sublethal but can become lethal in combination with other solid wastes. Polystyrene plastics are detrimental to humans. Without proper implementation of disposal methods, dumping or burning of these polymers leads to serious risks such as cardiac malfunction, severe respiratory problems including asthma and emphysema, vomiting, kidney or liver damage, and damage to the reproductive system. Dioxins deposit on the surface of plants and aquatic systems and find their way to enter the human food chain. Significant phthalate pathways include direct releases into humans consuming plastic-contaminated materials, unknowingly. Several chemical substances such as bisphenol A (BPA) are added to the plastic polymers to enhance their applications. Lethal monomers have been linked to cancer and reproductive problems. Marine and fresh water animals face huge problems due to the plastic pollution.

5. Conclusion:

In the world we inhabit, exposures to plastics, plasticizers, and other polymer additives are omnipresent. While these are often expected to be below critical threshold numbers, in some cases, excessive amounts are recognized, causing major impacts on certain sensitive communities of the environment. Although the potential risk due to plastic wastes is likely to vary according to the type, it has an adverse impact on the environment. Microplastic debris consumed by marine organisms poses a threat to human beings. Moreover, the deposition of plastic debris in soil leads to soil corrosion and landslides. The impact of these pollutants has to be addressed carefully to identify the associated hazards. Dumping plastic or simply burying it in the soil is a threat to the environment. Reduce, reuse, and recycle are keywords for plastic management. However, owing to the nonavailability of life cycle assessment (LCA) and lack of sound knowledge on disposal techniques and remediation of soil and environment from plastic waste, the question of disposing of plastic waste remains a big challenge. New innovations in the field of solid waste management are in nascent stages and need to be explored by researchers.

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Departmental Events

2023

CHEMSPARK’23

21st April 2023

CHEMSPARK'23

21st April 2023

Chemspark is a bi annual event Organized jointly by the Department of Chemical Engineering, Heritage Institute of Technology, Kolkata and IIChE Students' Chapter-HIT(K) supported by IQAC.

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ChemSpark '23 was a one-day programme that aimed to provide a platform for students and professionals in the field of chemical engineering to come together and share their ideas and knowledge.

Chemspark'23 was hosted by:
Diptendu Dutta (convenor)
Sangita Bhattacharjee (convenor)
Student coordinators:

- Ritam Das
- Arunava Das
- Hritama Jana
- Praneel Bhattacharya

This years chemspark consisted of the following events :
Inaugural Proggrame
Technical talks
AutoCAD Competition
Technical Quiz

And it was concluded by a Valedictorian session.

INNAUGRAL PROGRAMME

INNAUGRAL PROGRAMME

The Inauguration commenced with a Welcome address by Prof. (Dr.) Basab Chowdhary, Principal of Heritage Institute of Technology Kolkata, delivered virtually. He expressed his enthusiasm for the event and commended the efforts of the organizing committee, which was followed by the lighting of the lamp ceremony.

The distinguished dignitaries who participated in the lamp lighting ceremony were Mr. Pradip Agarwal, CEO of Heritage Group of Institutions, Probir Roy, Executive Director of Kalyan Bharati Trust, our esteemed chief guest Prof. (Dr.) Samit Roy, HOD, Polymer Science & Technology, University of Calcutta, and Mr. Abhijit Mitra, Chairman CRC, IIChE.

Subsequently, Professor (Dr.) Sulagna Chatterjee, Head of the Department of Chemical Engineering at Heritage Institute of Technology Kolkata, presented an Overview of ChemSpark 2023, highlighting the department's achievements and the significance of this event.

The event progressed with an address by Mr. Pradip Agarwal, CEO of Heritage Group of Institutions, and Mr. Prabir Roy, Director of Kalyani Bharti Trust.

FELICITATION

The distinguished guests were then felicitated for their contributions in the field of engineering and education. Mr. Pradip Agarwal felicitated our chief guest Prof. (Dr.) Samit Roy, HOD, Polymer Science & Technology, University of Calcutta, whereas Mr. Probir Roy, Executive Director, Kalyan Bharti Trust, felicitated Mr. Abhijit Mitra, Chairman of the Calcutta Regional Centre (CRC) at Indian Institute of Chemical Engineers (IIChE).

Finally, the session was addressed by Mr. Abhijit Mitra, Chairman CRC, IIChE, and our chief guest Prof. (Dr.) Samit Roy, HOD, Polymer Science & Technology, University of Calcutta. The Inaugural session concluded with a Vote of thanks dedicated to our principal and HOD, and all the esteemed dignitaries who graced the occasion.

TECHNICAL EVENTS

TECHNICAL EVENTS

TECHNICAL TALKS

Under the auspices of knowledge, the day's events commenced with a trio of technical talks:

- Dr. Debarati Mitra, Associate Professor at the Chemical Technology Department of the University of Calcutta, delved into the arcane arts of 'Desulfurization of Model Diesel Using Synthesized Ionic Liquids via Solvent Extraction.'
- Mr. Saptarshi Majumder, Product Application Engineer at KLA Corporation, California, USA, offered a glimpse into 'A Chemical Engineer's Perspective in Semiconductors.'
- Dr. Jayanta Chakraborty, Associate Professor at the Department of Chemical Engineering at IIT-Kharagpur, India, highlighted the importance of 'Particle Technology: A Hitherto Neglected Education: Why It is Vital for Current and Future of Chemical Engineering?'

AUTOCAD COMPETITION

In a first of its kind, an AutoCAD competition was held, inviting the second, third, and fourth-year students of our department to showcase their talents. The participants gave their all, and the competition witnessed keenly contested designs.
The victors of this year's competition were: **Sagnik Das** ChE (3rd year) in first place, **Soumyabrata Tewary** (3rd year) in second place, and **Arka Sanyal** (3rd year) in third place.

TECHNICAL QUIZ

The day's activities also saw the prelims of the Technical Quiz Event, conducted by the illustrious Prof. (Dr.) Abhuday Mallick, as the Quizmaster. The top five teams were selected for the finals, where they battled with their knowledge of the arcane arts.

With the last of the events winding to a close, the valedictory session celebrated the winners of the day's events, capping off another successful edition of Chemspark 2023.

INDUSTRIAL VISIT

A group of 17 sharp-minded students, led by Prof. (Dr.) Abhyuday Mallick, with a keen interest in Petroleum Refinery Engineering, recently visited IOCL's Lube Oil Blending Plant and Testing Facility located in Kolkata's Paharpur.

The students aimed to obtain first-hand knowledge of the latest Lubricating Oil production techniques, performance parameters, and market trends. During their visit, the students toured the ultra-modern Quality Control Laboratory where they observed advanced equipment and instruments they are currently studying in their course being put to the test.

The laboratory was equipped to perform a range of tests, including Kinematic Viscosity, Cloud point and Pour Point, Closed Cup and Open Cup Flash points, Copper Strip Corrosion, Elemental Analysis by FTIR and EDXRF, among others.

The General Manager, Quality Control, Mr. Biswanath Chattopadhyay personally engaged with the students, providing insights into different aspects of Lube oil performance and quality analysis.

The Department of Chemical Engineering at Heritage Institute of Technology extends its appreciation to the HITK administration and IQAC for their support.

A special thanks to Mr. Bikram Ghosh, IOCL, for coordinating the visit, and for promoting the Department as a proud alumnus (2015 batch).

Overall, the visit was an enriching and enjoyable experience for all the attendees.

The group with Plant Head, GM QC, our alumnus Mr. Bikram Ghosh

INDUSTRIAL VISIT

Mr. Biswanath Chattopadhyay, GM, QC, being felicitated by Dr. Abhyuday Mallick

CREATIVE WRITING

In a hushed tone she weeps.
Once glorious,
Now sorrowfully sleeps.
Echoes of a fading World.

Verdant fields, then full of life,
Lost amidst her muted cries.
Betrayed by her own blood,
Slowly succumbs to her death—
Our Mother Earth.

We watch as the mountains crumble,
The oceans rise;

The knell of a planet's demise.
We see the concrete jungles sprawl,
Expanding cities devouring all.

Whispers of a Dying Earth.
A reminder of our fragile worth.
We, her children, must strive
To keep her alive;
In our actions, let compassion reign,
And let the world flourish
For generations to gain.

Whispers of a Dying Earth

Aaishani Choudhury (1st Year)

FROM YOUR ELIZABETH BENNETT

In the gardens of my spirited mind,
Where love's sweet whispers intertwine,
I wander through a world of pride and wit,
Where hearts intertwine, in passions fit.

Oh, Mr. Darcy, enigma of grace,
A soul veiled, with a captivating face,
Within your gaze, a hidden fire,
Stirs a longing, a burning desire.

In your presence, my spirit soars,
For wit and intellect, my heart implores,
The dance of words, a playful duet,
Our banter, a symphony I'll never forget.

Your proud facade, a shield so strong,
Yet my heart senses a love so long,
In moments stolen, beneath the moon's soft light,
I catch a glimpse of a tender Knight.

But pride, my dear, is not my friend,
A prejudice that clouds my vision's blend,
Yet, slowly, surely, my heart reveals,
that true love's flame, it never conceals
In fields of green and whispers shared,
Our hearts entangled, no secret spared

Through misunderstandings, a love unbound,
Grows deep and true, with every sound.

Oh, Mr. Darcy, unravel your pride,
And let love's current be our guide,
For in your arms, I find my peace,
A love spun true, a sweet release.

Release the barriers, let love unfold,
Our story, a drape of diamond and gold,
Together, we traverse life's winding road,
Our hearts entwined, forever bestowed.

Let us leap into love's embrace,
With courage and faith, let's efface,
All doubts and shadows that have confined,
The love that blooms within our kind.

For, Mr. Darcy, in your love I've found,
A strength within, a new profound,
And as we journey, heart to heart,
Our love, forever, shall never depart.

-Soumili Sarkar, 3rd Year

Dance and Mental Health

A Harmonious Connection

For generations, dance has been a vital component of human civilization as a universal method of self-expression. Beyond its aesthetic and cultural significance, dancing has tremendous therapeutic potential for mental health. This essay delves into the therapeutic advantages of dancing on psychological, emotional, and social elements of individuals' life, diving into the deep relationship between dance and mental well-being. Dance is a strong outlet for releasing pent-up emotions. People can freely express themselves through dance, whether they are happy, sad, angry, or anxious. Dance's physicality allows people to express their feelings, providing a safe and healthy outlet for emotional release. Dance's rhythmic and repeated movements can generate a state of relaxation and mindfulness, reducing cortisol levels and increasing calm. This impact is very useful in our fast-paced, stressful modern life. Dancers receive a sense of satisfaction and self-worth as they learn and perfect new techniques and routines. This newfound confidence frequently spills out onto the dance floor, favourably influencing other facets of their lives. Dance promotes body positivity by encouraging a healthy relationship with one's own body. Dancers learn to value their bodies for what they can perform rather than how they appear. This adjustment in perspective can aid in the treatment of body image disorders and the enhancement of self-confidence. Dance frequently involves being a member of a community or group, which can help to alleviate feelings of isolation and loneliness. These social relationships, whether through a dancing class, a dance team, or a cultural dance group, can be beneficial to one's mental health. Dance is a nonverbal form of communication that teaches people how to express their emotions, stories, and ideas via movement. This ability improves interpersonal communication and teamwork, both of which are necessary for maintaining successful relationships. Memory and cognitive function can be improved by learning choreography and memorising dance routines. This mental activity has been shown to reduce the risk of cognitive decline and dementia in older persons. Dance fosters creativity by allowing individuals to develop their own unique ways of moving and interpreting music. This creative activity has the potential to excite the intellect and inspire innovation in other aspects of life. Dance movement therapy is a recognised type of psychotherapy that addresses psychological disorders via dance and movement. DMT sessions are led by qualified therapists and have been shown to be useful in treating depression, anxiety, and trauma. Dance therapy can help with a variety of mental health issues. As an example:

a. **Depression:** Dance has been shown to improve mood and motivation, offering an alternative to standard talk treatment.
b. **Anxiety**: Because dancing is structured, it can help relieve anxiety by offering a sense of control and predictability.
c. **PTSD:** Through movement and expression, dance can help people process painful situations.
d. **Autism Spectrum Disorder :** Dance therapy has been used to help people with autism improve their social skills and communication.

Accessibility is one of the difficulties in using dance for mental health. Dance classes and dance therapists are not available to everyone, which limits the potential advantages of dance for some people. Despite increased acceptance of dance therapy, there is still a stigma attached to getting help for mental health problems. Some people may be hesitant to undertake dance therapy because they are afraid of being judged or because of societal stereotypes. A burgeoning movement is attempting to include dance therapy into mainstream mental health care. Hospitals and mental health facilities are beginning to include dance therapy as a treatment option, recognising its usefulness in supplementing standard therapies. The number of community-based projects promoting dance for mental health is growing. These programmes seek to make dance more accessible to a broader audience while emphasising the importance of mental health. Dance emerges as a powerful and holistic way to supporting mental well-being in a world when mental health challenges are on the rise. Its ability to relieve emotions, boost self-esteem, establish social relationships, increase cognition, and function as a therapeutic tool makes it a great resource for people looking to improve their mental health. Dance and mental health have a bright future, with growing acknowledgement of its potential benefits and initiatives to make it more accessible to all. Dance provides emotional and psychological healing as well as physical expression, reminding us that movement has the potential to heal and transform the human spirit.

-Tulika Bhattacharya 3rd Year

SHUTTER STRUCK

Kaninika Dey
(1st Year)

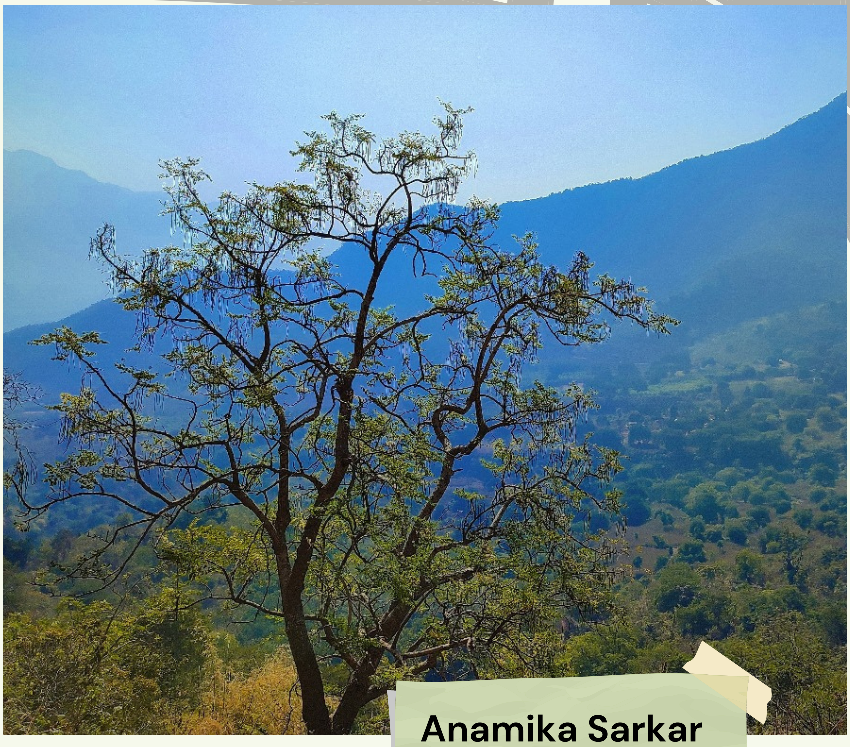
Aryan Saha
(4th Year)

Pallavi Rom
(2nd Year)

Turya Parbat
(3rd Year)

Souradip Mitra
(2nd Year)

Agniv Ghosh
(2nd Year)



Anamika Sarkar
(4th Year)

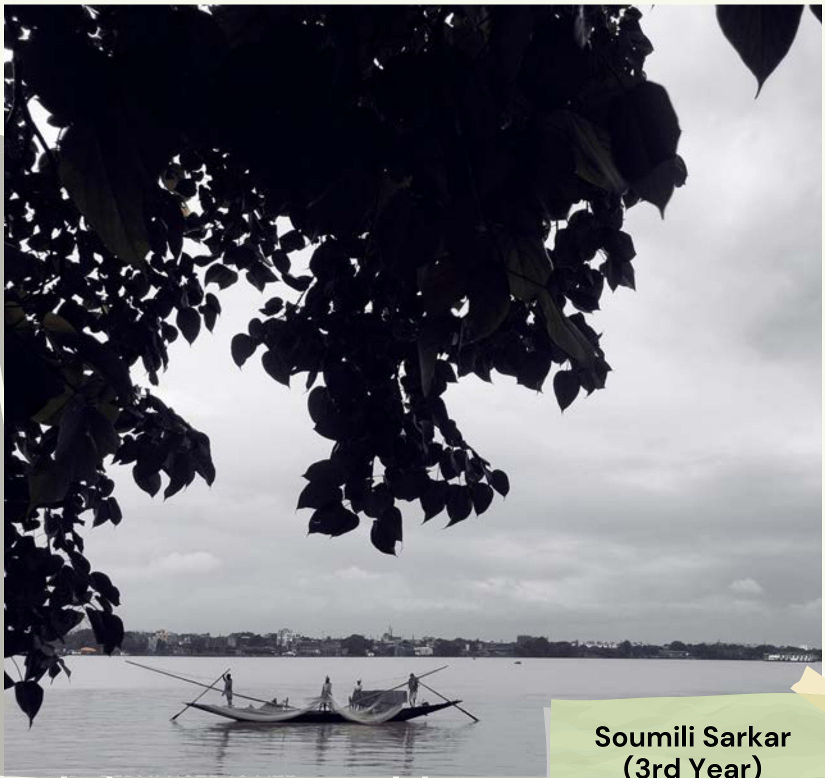
Kinjal Kumar Dey
(3rd Year)

Praneel Bhattacharya
(4th Year)

Soumajeet Das
(3rd Year)

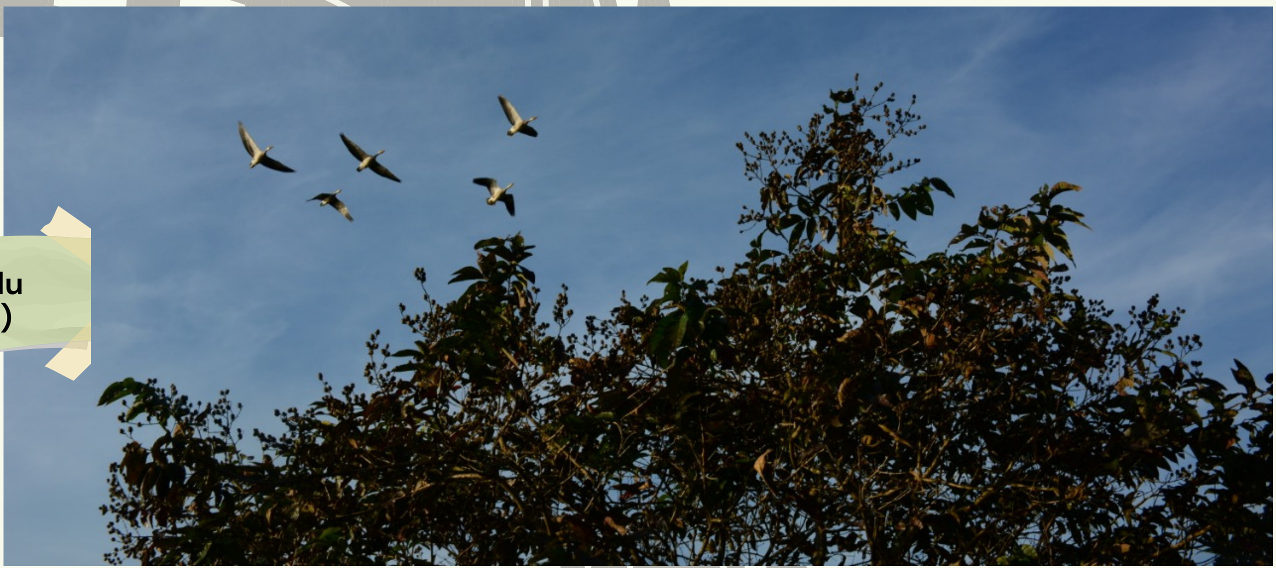
Debtaru Chatterjee
(3rd year)

Devaditya Goswami
(2nd Year)



Soumili Sarkar
(3rd Year)

Sayan Chatterjee
(2nd Year)



Ishita Kundu
(2nd Year)

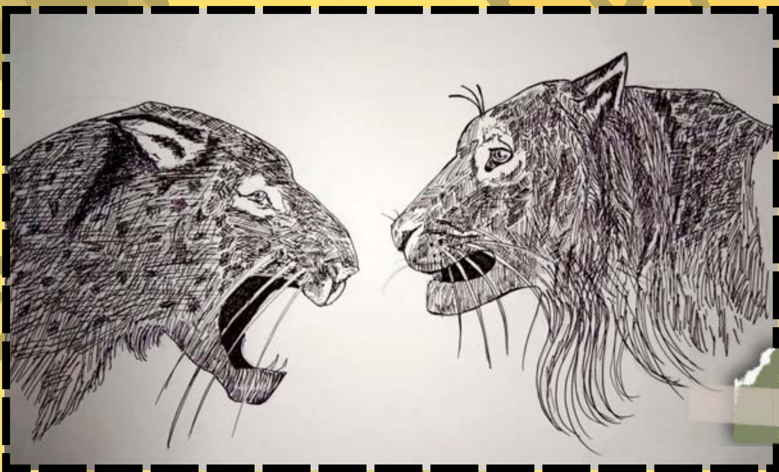
Sayan Das
(2nd Year)

Artistic

Canvas

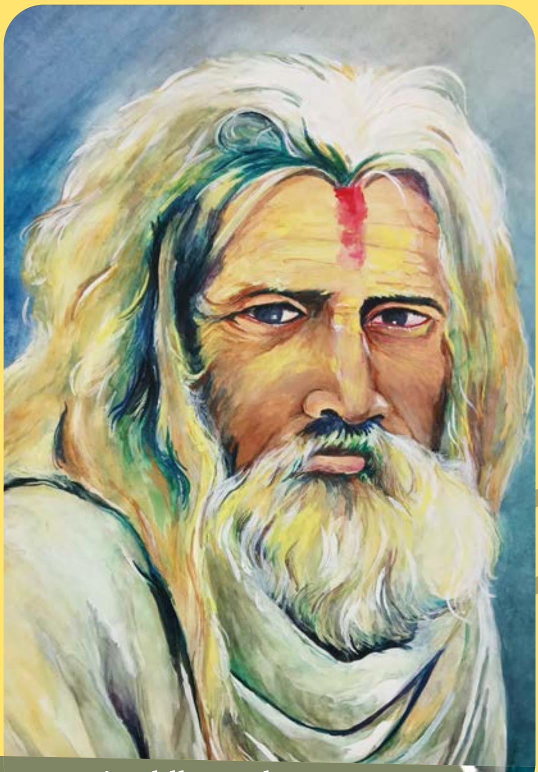
Kinjal Kumar Dey
(3rd Year)

Souroja Mukherjee
(3rd Year)



Soumili Das
(3rd Year)

Anwesha Nandy
(3rd Year)

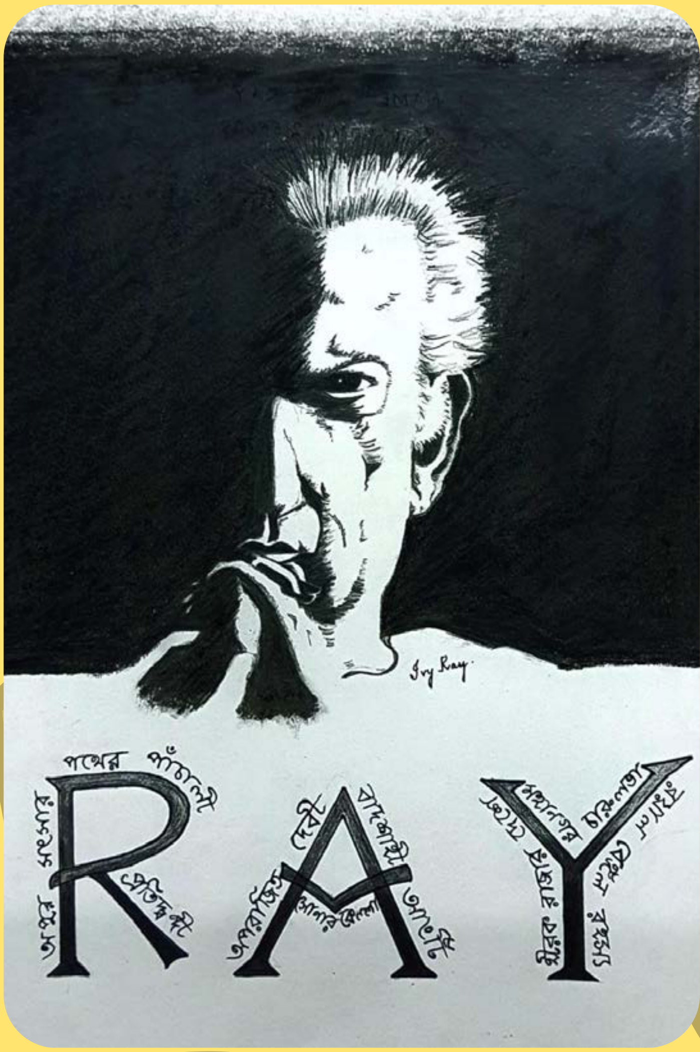


Aniruddha Sarkar
(2nd Year)

Soukanya Paul
(3rd Year)

Debojit Seal
(1st Year)

Rajrupa Bhattacharjee
(2nd Year)



Ivy Ray
(3rd Year)

Anirudhha Sarkar
(2nd Year)

RECONNECTION

The name "Heritage" always takes me down a memory lane full of joyous days. That day is still fresh in my mind when 12 years back, I first stepped inside the B building classroom of the huge campus which later became a "second home". I can undoubtedly say that Chemical Engineering Department, Heritage Institute of Technology has shaped up my future and I will remain indebted to the ever-supporting faculties for their teachings and for always being present to solve our queries at any odd hour of the day. Have made friends for life with whom conducting the long Mass Transfer laboratory experiments or preparing a difficult design in Autocad, all were fun. The faculties always gave us glimpses of opportunities in the outside world apart from classroom teaching and thus when I graduated in 2011 and stepped into IIT Kharagpur for my Masters, I felt prepared enough to face the bigger world. Keep shaping future, dear Alma Mater.

Dr. Ishita Sarkar
Scientist, CSIR-CMERI
Batch of 2011

As I reflect the time spent in Heritage, I am flooded with memories, learnings, experiences that have shaped me. As a passout student of Department of Chemical Engineering my heartfelt message to all my lovely juniors is that cherish every single day spent in the college, challenge yourself , have the courage to find your inner strength, treasure the knowledge imparted by professors, find your passion. Build your life, career and friendships.

Sujata Sen
PhD student
IIT Delhi
Batch of 2016

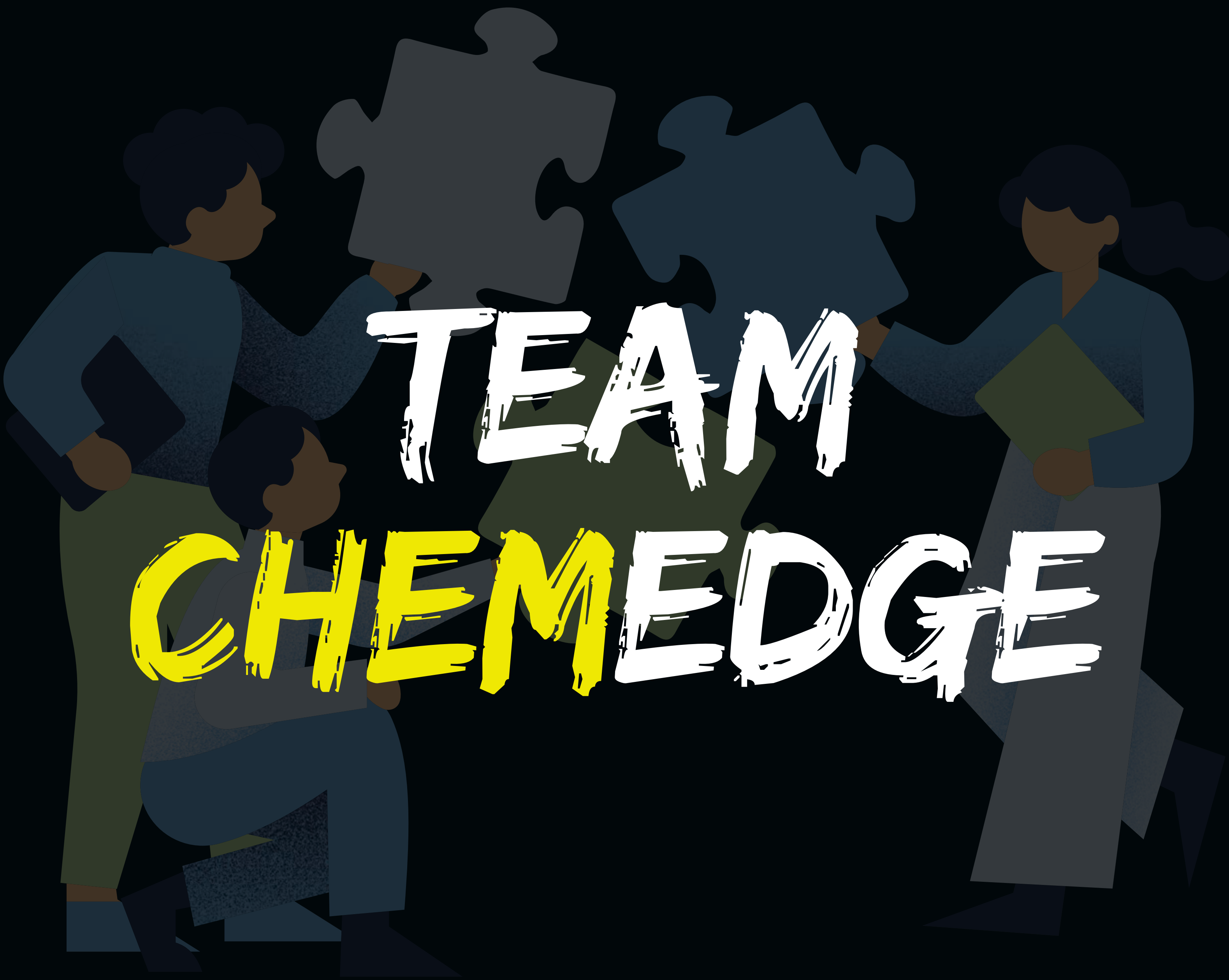
CLASS PHOTOGRAPHS

1st Year

2nd Year

3rd Year

4th Year


TEAM
CHEMEDGE

EDITORS

SOUMAJEET DAS
3rd YEAR

KINJAL KUMAR DEY
3rd YEAR

ARNESH DE
3rd YEAR

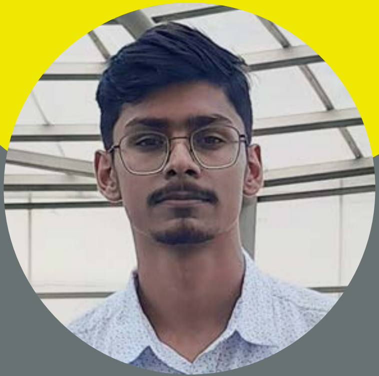
SAYAN CHATTERJEE
2nd YEAR

DEVADITYA GOSWAMI
2nd YEAR

PR TEAM

AYUSHMAN MALLICK
3rd YEAR

SAUBHAGYA MUKHERJEE
3rd YEAR



SOURADIP MITRA
2nd YEAR

TURYA PARBAT
3rd YEAR

SOUMILI DAS
3rd YEAR

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THANK YOU

SEND US YOUR FEEDBACK HERE:

https://forms.gle/jHR4qJNwafQwj9s68