EMERGING TRENDS IN CHEMICAL AND ENVIRONMENT SCIENCE FOR SUSTAINABLE DEVELOPMENT

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Green Chemistry and Sustainable Practices

Rachana Methi*

Introduction

Principles of Green Chemistry

When we talk about fundamental green chemistry, we are referring to any chemical process or approach that improves not just the quality of our lives but also the surroundings. A singular contribution has been made by chemists in the process of establishing the conditions necessary for sustainable development. In order to achieve this goal, Paul Anastas and John Warner have devised a set of guidelines for "green chemistry," which they believe will result in the creation of chemicals, processes, and products that are less harmful to the environment. The following are the guiding themes that will be presented.

- **Prevention:** In order to avoid having to deal with rubbish after the fact, it is best to avoid waste in the first place.

Zero waste technology (ZWT) development is the primary objective of the first principle. For a chemical synthesis to be considered ZWT, there must be no or very little waste product. Its secondary goal is to recycle materials from one system's byproducts into those of other systems. There are several potential uses for wastewater, including in thermal power stations as cooling water, in the cement and brick industries as a raw material, in municipal trash as an energy source, and in the cleaning of machinery as effluent. There are several examples of this. The waste product will be reduced by these techniques.

- **Atom Economy:** In the process of constructing synthetic processes, the most important objective should be to include as many raw ingredients as possible into the final product.

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- **Less Hazardous Chemical Syntheses:** It is essential that synthetic methods give priority to the utilization and production of chemicals that are either low in toxicity to humans and the environment or completely non-toxic within the scope of their use.

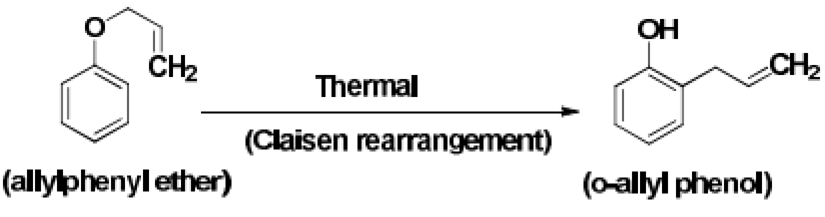
The focus of this guiding notion is on techniques that lessen the generation of dangerous chemicals as well as the utilization of such compounds. That is to say, synthetic processes should make use of and manufacture compounds that are safe for both humans and the environment, not displaying any toxicity at all or very little toxicity at all.

- **Designing Safer Chemicals:** The development of chemical products need to have as its primary objective the accomplishment of their intended function with the least amount of toxicity achievable.

Both the raw materials and the byproducts that are produced by many chemical companies are considered to be hazardous to both people and the environment. As an illustration, adipic acid is utilized extensively in the manufacturing process of a variety of polymer goods, including nylon, polyurethane, lubricants, and others. In spite of the fact that benzene is a volatile organic compound (VOC) and a carcinogen, it is utilized as an intermediary in the manufacturing of adipic acid, which is a contributor to the emissions of pollutants into the atmosphere. As part of the ecologically friendly technique that Drath and Frost developed, enzymatic production of adipic acid from glucose is one of the components.

- **Safer Solvents and Auxiliaries:** When it is possible to do so, it is advisable to steer clear of the use of potentially hazardous auxiliary chemicals, such as solvents or separation agents.

This strategy is based on the concept of substituting more ecologically friendly alternatives, such as water and supercritical carbon dioxide, with volatile halogenated organic solvents such as CH2Cl2, CHCl3, C2Cl4 (perchloroethlene), and CCl4. Our preference is toward solvent-free synthesis wherever it is feasible. One example of a rearrangement that may be performed in the solid phase is the Claisen modification.



Scheme 1: Claisen Rearrangement in Solid Phase

- **Design for Energy Efficiency:** Because of the detrimental consequences that chemical processes have on both the economy and the environment, it is essential to restrict the amount of energy that is required for these processes.

To achieve the best possible results, synthetic operations should be carried out at ambient temperature and pressure.

In order to lessen the amount of energy that is consumed, synthetic processes have to be carried out in surroundings that are more temperate, with the appropriate temperature and pressure being the ambient conditions. It is necessary for it to have catalysts, sometimes known as enzymes, in order for it to work in natural surroundings.

There is a plethora of additional options available for reducing energy consumption. Some of these options include: refluxing, which uses less energy overall; reusing heat from reactions to heat reactants and other materials; improving heating system technology; favoring photochemical reactions (especially those that make use of solar radiation) over thermochemical reactions; utilizing microwave heating; and many more.

These techniques encourage the use of renewable energy sources, which is in agreement with the sixth principle.

- **Use of Renewable Feedstock:** When it comes to feedstocks or raw resources, it is desirable for them to be renewable rather than declining whenever it is practicable to do so.

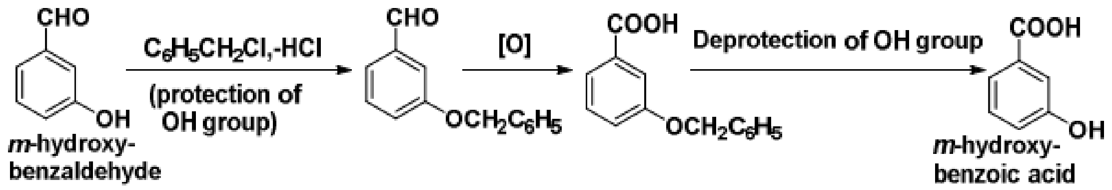
In the event that it is viable from a technological and economic point of view, it encourages the use of renewable raw materials or feedstock as the primary components of the material. As a result of overexploitation, which is defined as the continuous consumption of nonrenewable resources such as petroleum products and fossil fuels, these resources will ultimately be depleted, leaving future generations with a diminished supply of these resources. In addition, the exploitation of these resources that do not replenish themselves is harmful to the ecology.

On the other hand, if you want to ensure that resources are shared by future generations, you should make use of resources that are sustainable or renewable, such as agricultural or biological goods. In most instances, this approach does not do an excessive amount of damage to the environment. When everything is taken into consideration, the stuff and garbage are often biodegradable.

A number of examples have demonstrated the application of these principles in practice. These examples include the production of biodiesel, bioplastics and biopolymers (including PHB, PHV, PHVB, and BIOPOL, among others), carbon monoxide feedstock in the production of polycarbonate, furfural synthesis from biomass, adipic acid and catechol synthesis from biomass, and polylactic acid synthesis from biomass.

- **Reduce Derivatives:** In situations when it is possible to do so, it is better to minimize or avoid derivatization that is not essential. This include activities such as the utilization of blocking groups, the protection or deprotection of components, and the temporary modification of chemical or physical processes. It is possible for these processes to result in waste and require extra reagents.

Especially in the field of organic synthesis, it is not uncommon to have a functional group and its protection required. Last but not least, we have to make another request for their deprotection. In this example, we see how m-hydroxybenzoic acid may be produced by combining m-hydroxybenzaldehyde with that compound.



Scheme 2: Green synthesis of m-hydroxybenzoic acid from m-hydroxybenzaldehyde

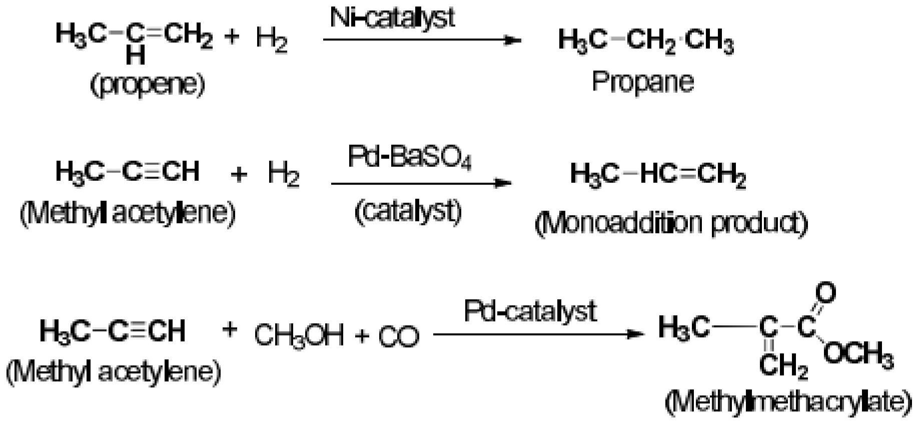
As a matter of course, the economy of atoms is likewise lower in these situations. During the process of creating a technology, the green chemistry concept calls for the elimination of unnecessary processes to the greatest extent feasible. When it comes to biocatalytic processes, the utilization of a selective group is frequently deemed unneeded.

- **Catalysis:** Catalytic reagents, which should be as selective as is practically possible, are superior than stoichiometric reagents in terms of their effectiveness.

According to this idea of green chemistry, stoichiometric reagents are inferior to those that are catalytic. The following advantages make catalysts an appealing option to consider going with.

- An economy that is entirely based on atoms, given that all of the atoms have been retrieved and their chemical and physical properties have not altered.
- Catalyzed processes are more efficient, which means they can consume less energy. This brings us to the second point.
- The outcomes are more positive than expected.
- The end result of a response that is selective.
- Maximizing the use of the starting resource while reducing the amount of trash produced

The following are some instances of catalytic processes that are in accordance with the completely atom-based economy:



- **Design for Degradation:** In the event that a chemical product has accomplished its intended function, it ought to break down into innocuous byproducts and not be allowed to linger in the environment.

This provision stipulates that the waste product must undergo natural decomposition in order to maintain the cleanliness of the environment. It is for this reason that the use of biodegradable polymers and insecticides is always an excellent choice. Under some circumstances, the photochemical degradability of polymers is necessary. It is essential to keep in mind that the goods that have been degraded should not possess any features that may be considered dangerous.

- **Real-time analysis for Pollution Prevention:** Improvements should be made to analytical processes in order to enable real-time monitoring and control of the process, which will help avoid the production of potentially hazardous substances.

There is a critical need for the creation or modification of analytical procedures in the chemical industries and nuclear reactors. This is because these techniques will enable continuous monitoring of the units that are responsible for processing and manufacturing. It is necessary to have this sort of efficient monitoring in order to prevent the accident.

- **Inherently Safer Chemistry for Accident Prevention:** It is essential to exercise caution while selecting compounds and their forms for use in chemical processes in order to lessen the probability of chemical accidents such as releases, explosions, and fires.

For the purpose of lowering the probability of accidents occurring, the compounds that are utilized in chemical industries have to be in particular categories. When it comes to chemical processes, the danger of explosion and other risks is significantly higher in those that deal with gaseous substances as opposed to those that deal with nonvolatile liquids or solids. In point of fact, the use of solid chemicals throughout the entirety of the process brings the risk down to an acceptable level.

Applications in Industry

Green chemistry is utilized often in a variety of sectors, including the chemical, pharmaceutical, paper, polymer, textile, and printing industries. In addition to its relevance in the field of energy sciences, it is also an essential component in the development of novel approaches to the production of energy storage devices such as fuel cells, batteries, and solar cells. In addition, green chemistry is utilized extensively in the fields of nanoscience and technology. There is a variety of green "next generation" catalysts that have been developed as a result of green chemistry. The primary goal of these catalysts is to reduce or eliminate chemical waste seen in industrial settings.

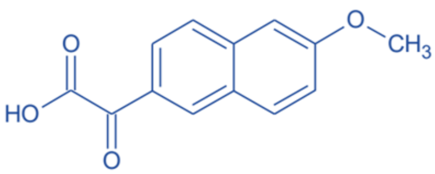
Green Chemistry in Pharmaceutical Industry

As a result of the significance of environmentally friendly chemistry, the pharmaceutical industry is undergoing a transition. Green chemistry allows pharmaceutical companies to conserve the environment while also increasing the production of medical chemicals. This is a win-win situation for everyone involved. There are millions of people who may potentially benefit from these ways that are less destructive and more successful, and there is hope for them.

BASF, a multinational chemical company, has reduced the number of steps involved in the production of the painkiller ibuprofen from six to three. Zocor (simvastatin), which is considered to be one of the most effective medications for high cholesterol, is often manufactured using a multi-step process that generates a significant quantity of hazardous waste due to the enormous quantities of hazardous chemicals that are utilized. Codexis, a company that specializes in biocatalysis, came up with an innovative method for the production of the medicine. This method makes use of a modified enzyme and a feedstock that is quite affordable. In order to extract paclitaxel, which is more often referred to as Taxol, from the bark of yew trees, a significant amount of solvent was required to kill the trees. The drug is now being produced in a fermentation tank by using tree cell cultures.

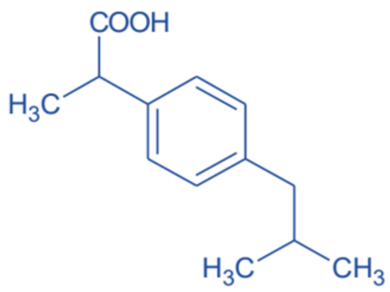
Examples of Drug Synthesized Using Green Chemistry

- The production of naproxen requires the utilization of a chiral metal catalyst that incorporates the BINAP (2,2'- bis(diphenylphosphino)-1,1'binaphthyle) ligand. Despite its moderate nature, the reaction produces outcomes that are adequate.



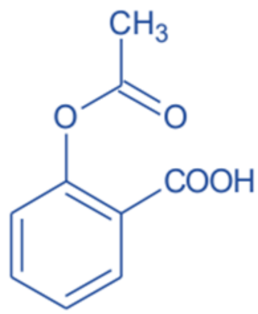
Naproxen

- During the manufacturing process of ibuprofen, an innovative method is utilized that reduces the amount of undesirable byproducts that are produced. An novel method known as "Green Chemistry" has been created for the manufacturing of ibuprofen, which is a nonsteroidal anti-inflammatory medication. In the year 1997, this improved synthesis was presented with the President's Green Chemistry Challenge Greener Synthetic Pathways Award.



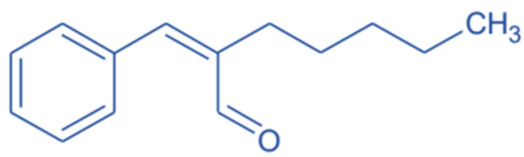
Ibuprofen

Using a solvent-free technique, aspirin was manufactured. This research shows that there is a new, more environmentally friendly way to synthesize than before.



Aspirin

The production of jasminaldehyde involves a condensation process between 1-heptanal and benzaldehyde at a ratio of 1:5, with chitosan serving as the catalyst. This reaction takes place in an atmosphere of nitrogen. By utilizing this method, the production of acids from aldehyde is prevented. Utilizing this technology results in a reduction in reaction time as well as the absence of any toxic byproducts.



Jasminaldehyde

Energy Science

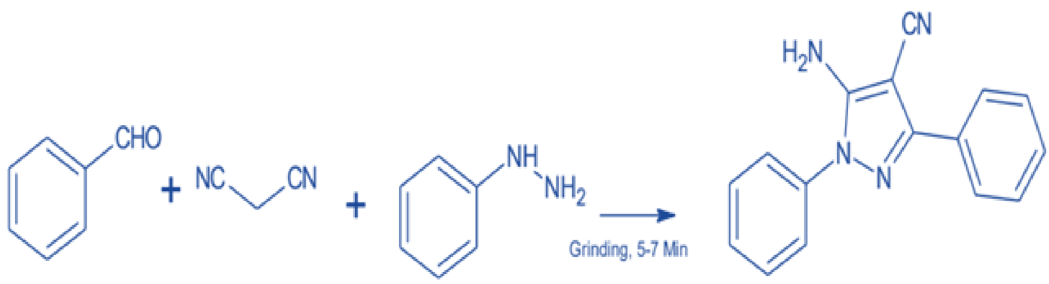
One of the potential options for green energy is the use of organic solar cells, which are not only economical but also beneficial to the environment. When it comes to the production of organic semiconductors, π-conjugated molecules and polymers are applied. The synthesis of conjugated systems is accomplished by the application of principles from green chemistry. When it comes to this matter, experts give preference to treatments that are less intrusive and make use of bio feedstock.

Eco-Friendly Dry Cleaning of Clothes

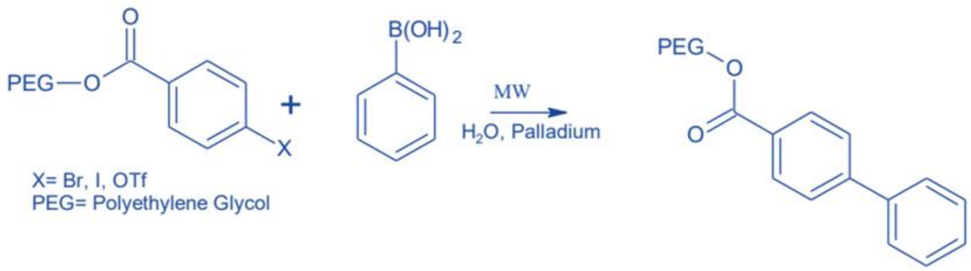
Perchloroethylene, often known as PEC, is a component that is used in dry cleaning and is known to cause cancer. Micell Technology has created a framework for cleaning metals that replaces halogenated solvents with supercritical carbon dioxide and a surfactant. Joseph De Simons, Timothy Romark, and James have devised a method for cleaning textiles that makes use of this combination.

Green Chemistry in Research Laboratories

In accordance with the principles of green chemistry, a great number of biocatalysts and green catalysts have been applied in the process of synthesising chemical molecules. Synthetic technologies that are environmentally friendly offer channels for reaction processes that are both safe and clean. Synthesis of polysubstituted amino pyrazoles was accomplished by the utilization of a simple, catalyst-free, one-pot, three-component technique. The grinding procedure was not very difficult. Using this method, we discovered that the majority of pyrazole synthesis methods need anhydrous conditions, costly catalysts, extended reaction times, an inert atmosphere, and a large number of stages.



Using solid-phase polyethylene glycol (PEG), highly fluorinated compounds are manufactured. It is possible to carry out this reaction in a risk-free manner with the assistance of the microwave. Considering that PEG is a soluble polymeric support for the synthesis of small molecules, subsequent purification is made more simpler by its presence.

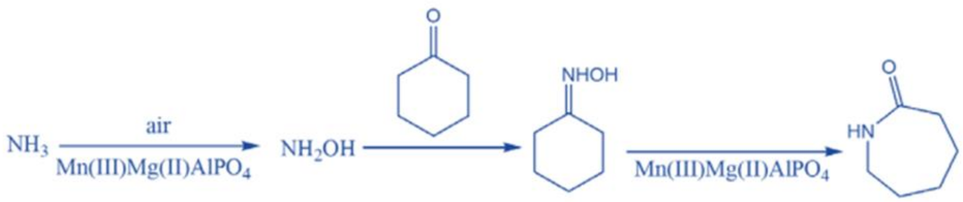


Clearing Turbid Water

By magnifying hazardous ions in treated water, alum contributes to the development of diseases such as Alzheimer's. Tamarind seed kernel powder, which is a byproduct of agriculture, has been given a new function, which is to clean and filter wastewater that comes from both residential and commercial sources. In this particular type of water treatment, kernel powder is superior to Al-salt due to the fact that it is non-toxic, does not suffer from perishability, and is economical.

Catalyst Design

There is a great deal of potential for improving the practices that are now used in manufacturing. An example of this would be the utilization of acidic and redox active site-distributed nanoporous aluminophosphate catalysts in order to produce o-caprolactam, which is a precursor to Nylon-6,6. This is a unique method of preparation. By utilizing one-step reactions that do not require the use of solvents, it is possible to reduce the amount of waste byproducts while simultaneously utilizing safe reagents.



Nanoscience Applications

Applications of nanomaterials may be found in a wide variety of sectors. Low-dimensional materials have a variety of applications in the technical world, and researchers are now working to develop these applications. Concerns about the environment are also at the core of the nanotechnology movement. The treatment of wastewater using mechanical and chemical methods, as well as the implementation of nanofiltration-based air purification, are now the subject of intensive scientific investigation. In recent years, the green chemical method has become an important technique for the synthesis of low-dimensional materials. This is due to the fact that it is environmentally friendly.

Chemical processes that are environmentally friendly strive to achieve a number of laudable aims, including reduced agent selection, avoidance of surfactants, increased yields, size distribution, and purity. Citrate, tollens, ionic liquid, polysaccharide, ligand exchanging, and polyoxometalate are some examples of the chemical synthesis procedures that fall under the purview of green chemistry. Reducing gold salts with citrate anions is a technique that was invented a few decades ago that created nanoscale gold particles that were practically monodispersed. During a sucrose ester micellar-mediated synthesis, the incorporation of NaOH played a significant role in accelerating the creation of silver nanoparticles. Derivatives of carboxymethylcellulose (CMC) had a dual role in the process of producing silver nanoparticles. Initially, they served to stabilize the silver ions before they were reduced.

Green Chemistry in Our Daily Lives

In light of these brief examples, it is abundantly evident that green chemistry is also an essential component of our day-to-day lives. It is common practice in the dry cleaning business to make use of the solvent known as perchloroethane, or PERC. Through collaboration with his colleagues, Joseph was able to develop the cutting-edge Micell technology. Dry cleaning was accomplished by the utilization of liquid carbon dioxide, which served not only as a solvent but also as a surfactant in this particular procedure. Therefore, halogenated solvents are no longer required as a result of the utilization of this cutting-edge dry-cleaning technique.

The use of used and exhausted vegetable oil as a fuel for automobiles has been demonstrated by researchers to cut carbon dioxide emissions by around 67% without sacrificing vehicle performance. This is accomplished with relatively few modifications to the vehicles that are now in use. What a surprising discovery this is. Paper manufacturing also makes use of two solvents that dissolve wood: sodium hydroxide (NaOH) and sodium sulfide (Na2S). Both of these substances are known as acids.

This mechanism is responsible for the breakdown of around 80–90% of the lignin that is present. Chlorine gas, commonly known as Cl2, is utilized in the process of removing any residual lignin from paper. However, it also reacts with the aromatic ring of lignin, which leads to the development of dioxins, which are known to be very carcinogenic. All kinds of life are put in jeopardy by these halogenated compounds since they are able to enter food chains. As a result, green chemistry offers a variety of bleaching chemicals that are not harmful to the environment. These compounds include hydrogen peroxide (H2O2), oxygen, and ozone. Consequently, detergents for laundry that include these bleaching compounds are more water efficient than other detergents.

In Environmental Safety

Increasing amounts of pollution in the environment are a direct outcome of people's use of plastic. It is common knowledge that plastic and the byproducts of plastic are found in both the food supply and the environment, and that these substances constitute a risk to the health of an individual. Consequently, the utilization of biodegradable plastics is aimed at lessening the influence that we have on the environment, with the ultimate objective of making the world a better and more sustainable place.

When conducting this review, it is important to take into consideration the goals and priorities of producing a wide range of biodegradable polymers over their entire life cycle. Biodegradable plastics have the potential to give all of the same functionality as ordinary plastics, provided that the appropriate waste management techniques are put into place, including composting. Additionally, biodegradable plastics can aid the environment in other ways, due to their decreased carbon dioxide footprint.

Lactic Acid Production Optimization

The first step in the manufacture of poly-lactic acid is the creation of lipid acid. The objective of the project was to discover a method that would allow for the production of lactic acid from agro-industrial waste by making use of renewable resources in a manner that would be both cost-effective and yield the additional advantage of reducing the levels of environmental pollution. The waste from the agricultural and industrial sectors also produced sixteen different types of bacteria. Within the context of this chemical hydrolysis process, hydrochloric acid, sulfuric acid, and sodium hydroxide were utilized in order to decompose waste from both industrial and agricultural sources.

A significant amount of lactic acid was created by 16S rRNA, as was discovered. This resulted in the identification of the conditions that are most conducive to the production of lactic acid. Calcium lactate, which was produced as a byproduct of culture fermentation, was eventually transformed into calcium sulfate by the utilization of sulfuric acid. Through the process of evaporating the filtrate that included free organic acid, lactic acid was successfully separated.

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Environmental Nanotechnology

Preeti Bairwa*

Introduction

Nanomaterials for Environmental Applications

Fullerenes and carbon nanotubes (CNTs) are two examples of nanoparticles that are produced or manufactured. These nanoparticles are generated with the goal of applying certain techniques. With regard to environmental problems, the one-dimensional (1D) system, thin films, or two-dimensional (2D) surfaces have the potential to be exploited in a wide variety of applications in the fields of engineering, chemical engineering, and electrical engineering. These applications can be carried out as thin films with sizes ranging from 1 to 100 nm, or as monolayers in the solar cell or catalysis industry. The production of next-generation environmental sensing systems, sensors for chemicals and biology, fiber-optic systems, optical and magneto-optical devices, and other technical applications are all examples of the many technological applications that make use of these thin films.

The sun is a renewable source of energy that does not do any damage to the environment and does not produce any ambient noise. It also emits an infinite amount of light. The use of solar electricity more than compensates for the use of nonrenewable energy sources, such as the fossil fuels and petroleum reserves that are found across the planet. Solar cells have gone through a number of different stages of development from one generation to the next because of the role they play in the production of alternative energy.

Solar Cell

A device that directly converts solar energy into electrical current is referred to as a photovoltaic (PV) device. One example of such a device is a solar cell. In the

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field of photovoltaic technology, the solar cell is acknowledged as one of the most essential components. Silicon, a semiconductor material, is frequently utilized in the production of solar cells. One of the most common and beneficial properties of semiconductors is their capacity to change conductivity by the introduction of impurities into the crystal lattice of the semiconductor. Depending on whether they are constructed from a single rod of crystals or a block of multiple crystals, solar cells can be categorized as monocrystalline, multicrystalline, or nanocrystal-based. Multicrystalline solar cells are the most common type of solar cell. A significant number of p-n junctions are the fundamental components that make up the majority of solar cells. Electrons are responsible for the formation of electron-hole pairs, also known as e-h pairs. These pairs are then separated by a dipole electric field, and when they are exposed to light, they are able to generate voltage and current. In order to do this, the "built-in" electric field that is present at the interface between p-type and n-type materials is responsible for making this feasible. At the point where they meet, a region of strong dipole electric field is generated, which is distinguished by the appearance of charge separation.

The characteristics of a solar cell's current-voltage (I-V) characteristics are depicted in Figure 9, which is a normal functioning example. The current and voltage ð Þ I V are the outcomes that occur as a result of the generation of energy by a solar cell. Utilizing this method, the power curve may be determined. The vast majority of solar cells behave in a manner similar to that of diodes when exposed to darkness. This is because they permit a significantly greater current to flow through when biased forward (V > 0) as opposed to when biased backward (V < 0). Under the assumption of a perfect diode, the dark current density shifts in the following manner:

$$J_{dark} = J_o\left(e^{qV/K_BT} - 1\right)$$

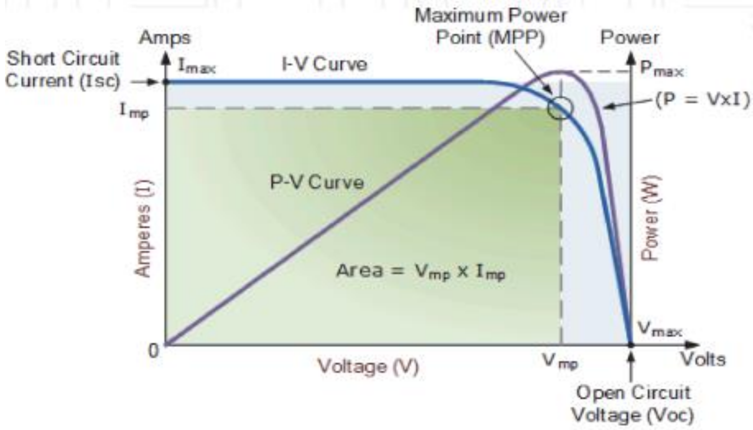
for the case where Jo is a constant value. The following is the net current that is going through a circuit that is powered by a solar cell:

$$J(V) = J_{sc} - J_{dark}$$

$$J(V) = J_{sc} - J_o\left(e^{qV/K_BT} - 1\right)$$

Voc, which stands for open circuit voltage, and Isc, which stands for short circuit current, are both defined. The fill factor (FF) is defined by the ratio [38], where Vm and Im are the maximum voltage and current, respectively, and where V=Vm and I=Im, respectively, provide the maximum power. The fill factor (FF) is a definition of the ratio.

Quantum efficiency (QE) is the ratio of charge carriers caught by the cell to the total number of photons that are incident on the device. This ratio is used in the measurement of photovoltaic (PV) systems.



(I-V) Characteristics of a typical PV cell

$$QE = \frac{P_{out}}{P_{in}} = \frac{P_m}{P_s}$$

Where is the maximum power and Pm = VmIm,Ps is incident light power.

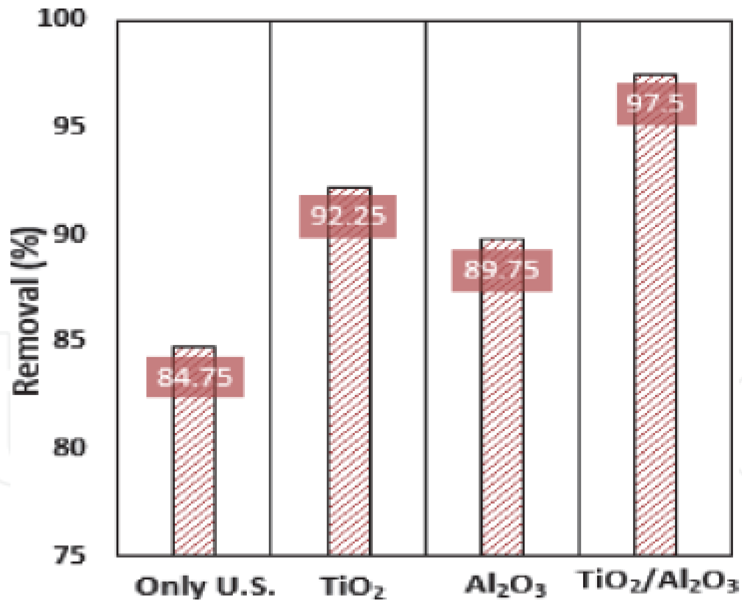
Nanocoatings

A continuous layer is what is known as a coating, and it is formed when coating materials are applied to a substrate in a single or several applications. The term "coating materials" refers to substances that, when applied, offer a covering that is both protective and visually beautiful. There are three possible forms that these materials may take: a liquid, a paste, or a powder. Certain nanoparticles can be utilized effectively through the use of transparent coating technologies. In addition, certain nanomaterials, such as TiO2 nanoparticles, are transparent when in the presence of visible light. This paves the way for the development of novel additives that can impart new qualities to coatings that would otherwise be opaque. The manufacturing technique that is to be utilized is determined by the precise application parameters of the coating as well as the planned usage of the coating. There are a number of possible advantages that the sol-gel process may offer to manufacturers, including a reduction in the amount of energy consumed, a reduction in manufacturing times, and a reduction in operating temperatures.

Because of its properties, which include low toxicity, high photocatalytic activity, chemical stability, and low cost, titanium dioxide was the compound that was employed the most frequently. There have been reports of paints that are capable of cleaning themselves also including other metal oxides, such as zinc oxide. The researchers that are working on self-cleaning systems are primarily concerned with factors such as air pollution and environmental contamination in buildings, particularly on the surfaces of interior and exterior building surfaces. Due to the wide variety of applications for self-cleaning agents, it was vital to focus on various materials for diverse applications. Although there is a complex link between the characteristics of self-cleaning surfaces and a number of surface aspects, there is a relationship between the two. Due to the fact that surfaces are initially superhydrophilic, it is easier to remove particles from them because water droplets are dispersed throughout the surface during the washing process. After that, these surfaces will be subjected to photocatalytic interactions with any organic coatings that are present on solid particles, which will make it simpler for the coatings to be removed by washing or falling off. Surfaces made of titanium dioxide have a relatively high electroconductivity. The antistatic properties of a surface are able to repel charged particles and prevent the accumulation of these particles on surfaces that have a high electroconductivity. The preparation of the mill base, which is used for dispersing the pigment in water and other solvents, is an additional stage in the process of manufacturing waterborne paint. The mill base and the binder, which is polymer latex, are combined in order to produce paint.

Sonocatalyst

As far as the chemical effects of ultrasound are concerned, there is no molecular connection between the acoustic field and the chemical species that are responsible for them. Sonochemistry and sonoluminescence draw their primary energy from sonic cavitation, not the other way around . A precipitous surge in the relevance of Sono electrochemistry’s growth has occurred over the course of the past few years. Ultrasonic vibrations have the potential to induce a broad variety of effects on electrochemistry processes. These effects can be attributed to the formation, subsequent expansion, and subsequent collapse of microbubbles in the electrolyte. Increasing emphasis is being paid to two areas: the fabrication of nano powders and the utilization of Sono electrochemistry for the purpose of environmental remediation . The versatility of ultrasounds allows for the development of novel applications for nanoparticle solutions that may be applied to a wide range of chemical components. According to reference, ultrasonic energy has the capability of breaking down molecular bonds. As a result of its various advantageous characteristics, such as its cheap operating cost, high efficiency, stability, and absence of secondary pollutants, the ultrasonic catalytic degradation process has found widespread use in the treatment of wastewater. A material that improves the efficiency of the ultrasonic catalysis process is referred to as a sonocatalyst. The mineralization of organic pollutants in water, such as synthetic colors, has garnered a lot of attention as a feasible and practical method for mineralizing these toxins. This process results in the production of hydroxyl radicals, which are extremely reactive and non-selective oxidants. These radicals have the ability to transform mineralizing and decolorizing dyes into carbon dioxide and water compounds. The oxidation processes are sped up when ultrasonic pulses are applied to the surface of a semiconductor made of metal oxide.



The sonocatalysis effect on MB decolorization

In the presence of semiconductor particles, such as TiO2 and ZnO, the formation of smaller microbubbles through ultrasonic irradiation was accelerated. This, in turn, led to an increase in the amount of high temperatures and pressures, which, in turn, led to the production of an excess of hydroxyl radicals that attacked the pollutant and degraded it. The impact of an Al2O3/TiO2/Al2O3 nanocomposite on the decolorization of methylene blue dye is depicted in Figure. Additionally, the sonochemical decolorization of dyes under initial concentrations is demonstrated by using an ultrasonic processor. Through their role as catalysts, nanoparticles accelerate the process of dye decolorization. They do this by increasing the rate at which water is dissociated into highly reactive hydroxyl radicals (OH) and by increasing the number of cavities that are brought into existence. TiO2/Al2O3 nanocomposites are superior to other sonocatalysts in terms of their ability to remove Methylene blue dye. This is due to the fact that they have high dissociation rates for H2O molecules, which allow them to generate a greater number of free radicals and speed up the degradation of organic compounds.

Safety and Risk Assessment

- **Why are nanoparticles considered dangerous?**

Because nanoparticles have a high surface area to volume ratio, they have the potential to be extremely reactive or catalytic. This makes them potentially hazardous. On the other hand, the majority of the safety concerns that are associated with these particles are yet unclear. In addition to this, they are able to traverse the membranes of living cells and have the ability to interact with a variety of biological systems.

- **Natural Nanoparticles and Possible Safety Concerns**

Agglomeration is a process that occurs fast among nanoparticles that occur naturally. This process transforms the nanoparticles from their nano-forms and results in them being safe to living organisms. As a result of studies carried out on animals, it has been shown that some nanoparticles had the capability to penetrate cells and tissues. These have the capacity to move throughout the body, and if they reach vital organs like the brain, they might potentially cause damage to the body's biochemistry or even cancer.

In addition, there are a great number of nanoparticles in the natural world, and it is possible that certain animals on Earth have acquired resistance to them. For example, terpenes that are formed from plants, salt particles that are found in ocean aerosols, and so on.

- **Risk for Nanomaterials in Use**

The possible long-term health risks posed by nanoparticles found in sunscreens and cosmetics require further study to be conducted on the subject.

- **How do Nanoparticles enter the body?**

Upon inhalation, nanoparticles have been demonstrated to have the potential to settle within the airways of both people and animals, as demonstrated by researchers. According to research conducted on animals, nanoparticles have the potential to penetrate the blood-brain barrier and end up in a variety of organs.

Particles derived from nanostructured materials, clusters of nanoparticles, or even single particles have the potential to make their way into the atmosphere or land on the skin of individuals.

Occupational Hazards with Nanoparticles

There are specific occupations that are more prone to expose workers to nanoparticles. All of them include:

- **Workers who are exposed to nanoparticles in liquid media are increasing their risk of skin** exposure if they do not use appropriate protection, such as gloves. Processes that involve a considerable level of agitation, such as pouring, mixing, or any other operation, might put workers in danger. There is also the possibility that the particles will be inhaled as a consequence of the agitation.
- Aerosolization is a potential that should be considered by anybody who works with nanostructured particles.
- It is possible for individuals who clean the dust collecting equipment that collect nanoparticles to be exposed to nanoparticles through their skin and respiratory systems.

Prevention of Nanoparticle Exposure

Despite the fact that the health risks connected with nanoparticles are not fully recognized, work practices and engineering control systems that are designed to prevent exposure to nanoparticles are well understood. When it comes to the utilization of potentially hazardous gases and chemicals, the majority of the procedures that are carried out are analogous to those that are carried out in traditional laboratories.

It is also important to specify other precautions, such as:

- It is essential for both safety and hygiene in the laboratory that lab coats be kept clean and worn on a consistent basis. The washing of lab coats in private dwellings is not permitted under any circumstances. When dealing with liquids that include nanoparticles, it is essential to wear protective arm sleeves in order to avoid excessive exposure or spillage due to the presence of nanoparticles.
- Each and every laboratory ought to be equipped with sinks or other appropriate locations for hand washing. Following the handling of nanomaterials, it is very necessary to properly wash one's hands.
- Each and every laboratory absolutely has to have a pair of standard Penn safety glasses.
- In the event that persons are dealing with nanomaterials, it is absolutely necessary for them to use disposable nitrile gloves.
- Long trousers and shoes with closed toes are elements that should be worn for appropriate dress.
- Ventilators and respirators are essential in order to prevent the inhalation of harmful substances.
- In the event that you are dealing with dry nanomaterials, you should only make use of a fume hood, biological safety cabinet, glove box, or vented filtration enclosure.
- The transportation of dry nanoparticles in containers that are hermetically sealed is required.
- In order to safely handle solutions that include nanoparticles, it is necessary to use bench covers that are disposable.
- Sonication, vortexing, and centrifuging are all examples of processes that are not permitted to be carried out on the open bench because they have the potential to generate aerosols. You can carry them out in a fume hood, a glove box, a biological safety cabinet, or a vented filtered enclosure, among other possible locations.

- It is necessary to use a HEPA vacuum in order to clean up any spills that involve dry nanoparticles. Using dry sweeping is not an appropriate method of cleaning. In order to clean up significant spills, electronic health record systems are necessary to be in place.
- There should be a lower amount of pressurization in the laboratory compared to the corridor. The management of ventilation in an appropriate manner is essential.
- Certain criteria have been established by the University for the disposal of hazardous waste, and these requirements must be adhered to for all solid goods and chemical solutions.

Environmental Effects

There have been very few studies that have concentrated on ecotoxicological testing in sedimentary and soil systems. Therefore, there has been less of an emphasis placed on methodology and practical approaches in the research that has been published. The aforementioned issues would also manifest themselves in the event that nanomaterial suspensions were combined with sediments and soils or sprayed upon them after being suspended in aquatic medium. Other methods, such as mixing or the direct application of nanomaterials, can also be utilized in order to apply treatment to soils and sediments. On the other hand, these systems also exhibit the same kinds of issues with regard to standardization. In light of this, the studies that are now being conducted to assess the dangers posed by nanomaterials in environmental models need to take into consideration the methodological variability that is connected with them. It is of the utmost importance to create and adhere to a standardized technique in order to decrease variability, guarantee that the results can be widely accepted and duplicated, and guarantee that the test materials, test organisms, and end goals are all correctly considered.

In the majority of instances, it is essential to make certain that the organisms being examined are compatible with the solutions used for examination in aquatic environments. All of the parameters, such as the amount of salt present, the pH level, the amount of solvent, and the kind of solvent, must be within the tolerance limits of the organisms that are being investigated. Nanomaterials that are organic and those that are inorganic are often treated with different methods depending on their composition. After being weighed into a water solution, nanoparticles comprised of inorganic materials, such as metals and metal oxides, are then mixed or ultrasonicated to ensure that they are evenly distributed throughout the solution. Finally, the nanoparticles are filtered. The dispersion of organic nanoparticles that are insoluble in water can be accomplished by the use of detergents. Alternatively, these nanomaterials can be dissolved in solvents such as benzene, tetrahydrofuran (THF), or toluene. Adding water and then draining off the solvent is all that is required to create a stable aqueous solution. On the other hand, there are indications that the fullerenes could still be soluble in the THF that was used to dissolve them, which might potentially render the solution dangerous (Zhu et al. 2006).

Environmental test Systems

- **Microbial Systems**

Microbes may be able to digest nanomaterials by a number of different methods, including as membrane rupture, selective or non-specific absorption, and diffusion. It was shown that the amount of humic acids present in soil and water was able to affect the bioavailability of C60 fullerene as well as its antibacterial activity. In the majority of instances, the possibility of adhesion to soil or sediment increases as the carbon content of the soil increases.

Gram-positive species are typically more severely affected than Gram-negative species, although generalized microbial effects have been observed to include membrane/membrane potential disruption, production of reactive oxygen species (ROS), protein oxidation/damage, interference with electron transport/respiration, and possible DNA damage.

- **Terrestrial Systems**

Some species were shown to have a few moderate effects after being exposed for short periods of time (24 and 48 hours), according to the findings. Single-walled carbon nanotubes, on the other hand, did not exhibit any signs of absorption. Copper nanoparticles had a detrimental effect on the growth of mung bean (Phaseolus radiatus) and wheat (Triticum aestivum) seedlings by finding a reduction in the development of the seedlings. This was accomplished via the utilization of a plant agar test technique. Through the use of transmission electron microscopy and energy dispersive spectroscopy, the researchers were able to observe the accumulation of copper particles within the cells.

As a result of the consumption of titanium dioxide nanoparticles (anatase) by terrestrial isopods (Porcellio scaber), it was shown that the enzyme activity for glutathione-S-transferase (GST) and catalase (CAT) was decreased. On the other hand, growth and survival as aggregate outcomes were not at all impacted by the experiment. The capacity of earthworms (Eisenia veneta) to breed was negatively affected when they were fed food that included double-walled carbon nanotubes that were present in the diet.

- **Aquatic Systems**

Certain characteristics of aggregation may result in exposures that do not necessarily correspond to the maximum doses. Concerns have also been raised regarding the use of solvents and the role that NOM plays as a nanomaterial stabilizer. On the other hand, greater dispersion does not always result in an increase in bioavailability or danger.

Methods of Assessment in Vitro

Within the realm of mammalian toxicity, research has been conducted that has contributed to the development of in vitro assessment methodologies. For example, oxidative assessment has been the focus of a number of different approaches, but genomics and proteomics are progressing at a more slow rate. It is also conceivable to employ other approaches that have been used in research involving mammals. For example, it is possible to evaluate the effects of nanomaterials on the function of fish hepatocytes by utilizing the enzyme lactate dehydrogenase (LDH) as a marker for cell toxicity.

It is helpful to link the impacts at different organizational levels when attempting to figure out how certain adverse effects might materialize and when considering the potential long-term ramifications of a situation. In vivo exposures are used to give a comprehensive method for effect assessment. This is then followed by the study of specific endpoints at the organ and organelle levels, in addition to biochemical endpoints. The in vitro research that were stated before are an excellent illustration of how to closely analyze the mechanistic implications at a particular organizational level.

Methods of Assessment in Vivo

Exposure media, the manner in which components are combined or suspended within the medium, and the actual exposures that need be taken into consideration have all been the subject of a great deal of discussion. In this regard, the characterisation of the nanomaterials that was carried out through the exposure studies has been a significant element. As a result of research conducted on sedimentary systems, this specific dispute got underway. In the disciplines of characterizing nanomaterials over time and combining them with sediments and soils, there is still a significant amount of work that has to be done by researchers. In this particular area, scientific advancements are still being made in the field of detection against a backdrop of naturally abundant elements such as carbon-based products, zinc, and silicon.

The field of ecotoxicology makes heavy use of endpoint integration, which encompasses the processes of food consumption, reproduction, and death. Additionally, certain biomarkers are frequently utilized in the process of evaluating the impacts of nanomaterials being utilized. Among them are techniques for determining the level of oxidative stress (in a single organ or throughout the entire body; for instance, lipid peroxidation), genetic damage, levels of CYT P450, gene expression, and damage to certain cell organelles (such the nucleus or mitochondria). In addition, cytological responses such as celluar necrosis and apoptosis have been utilized in this study. In spite of the fact that the procedures applied in these studies are often the same as those utilized in ecotoxicology research, modifications have been made in order to address the specific issue of particles or the influence of materials on the interpretation of results.

Significant progress has been made in the field of soil and sedimentary species research in recent years, despite the fact that there has been very little research conducted on these topics. Every single one of the created procedures has been in compliance with the standards given by the OECD, with the sole exception of the utilization of standard species.

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3

Waste Management and Recycling Technologies

Dr. Sneh Pareek*

Introduction

Advanced Recycling Methods

Advanced recycling is the process that takes place when plastics are refined or transformed into a feedstock for the production of new polymers, monomers, intermediates, or any other kind of material. This recycling process is also known as advanced recycling. It is also possible to refer to this procedure as "super recycling." Advanced recycling frequently alters the chemical structure of plastics by dissolving them in chemicals or breaking them down into their original components through heat. This is in contrast to mechanical recycling, which employs physical processes such as washing, grinding, sorting, and compounding without affecting the polymers. Mechanical recycling is frequently used. In contrast to this, mechanical recycling does not have any impact on the polymers when it is performed. Taking into consideration the fact that contemporary recycled materials are nearly indistinguishable from fresh plastic, it is feasible to build a wide selection of new things by using these resources.

When it comes to the chemical recycling of polymers, the following is an example of a process that does not include the presence of oxygen:

- **Polymer:** a large molecule made up of monomers
- **Monomer:** a molecule that can be bonded to others to create a polymer
- **Re-polymerization:** the process in which recycled monomers are bonded to create new polymers

Purification

Solvents are utilized in the process of purifying polymers in order to eliminate impurities such as aromatic compounds, colorants, and additives. There is preservation of the polymers, such as polypropylene, and they may be recycled into

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other articles made of plastic. In situations when there are many streams of plastic debris, filtration is the most effective method.

Depolymerization

Depolymerization of plastics into their component monomers, such as ethylene, can be accomplished by the use of biological, chemical, or thermal processes, or even a combination of these three methods. These monomers might then be employed as components for brand-new plastic products after they have been processed. It is more effective to use this strategy when dealing with plastics that are similar to one another as opposed to dealing with mixed plastic rubbish.

Conversion

The process of conversion involves the utilization of heat to break down polymers into their component elements, such as ethane, in order to render them usable once again as fuel or as a raw material for other plastic products. These kinds of advanced recycling continue to deliver high-quality recovered polymers even when processing plastic blends that are becoming increasingly complex.

Advanced Recycling in Action

One of the most common names for polystyrene is StyrofoamTM. Using this material, Agilyx, a company that specializes in alternative energy, recycles it into valuable petrochemicals. Compared to manufacture, the polystyrene recycling technology utilized by Agilyx results in the emission of less greenhouse gases while simultaneously generating new goods that are comparable.

Through the utilization of the polyester renewal technique, which was invented by Eastman, polymers from a wide variety of sources, such as carpet, soft drink bottles, and clothes made from polyester, are recycled back into their component monomers. Polymerization is the process that these monomers go through in order to form the final product.

Through the utilization of cutting-edge recycling technology that eliminates color, odor, and impurities, Purecycle is able to transform multiple streams of #5 plastic trash into polypropylene that is similar to virgin polypropylene. Despite the fact that polypropylene has a relatively low rate of reclamation, there is a possibility that the loop can be entirely closed for this durable and flexible material owing to the technology developed by Purecycle.

Among the most successful companies in the world in the fields of plastics, chemicals, and refining, Lyondell Basell stands out. Through the utilization of their MoReTec technology, they are recycling old plastics into ingredients that may be utilized to create new polymers such as polyethylene and propylene. The food and medical supply sectors are two of the numerous possible applications for the innovative resin that are now being considered.

Waste-to-Energy Technologies

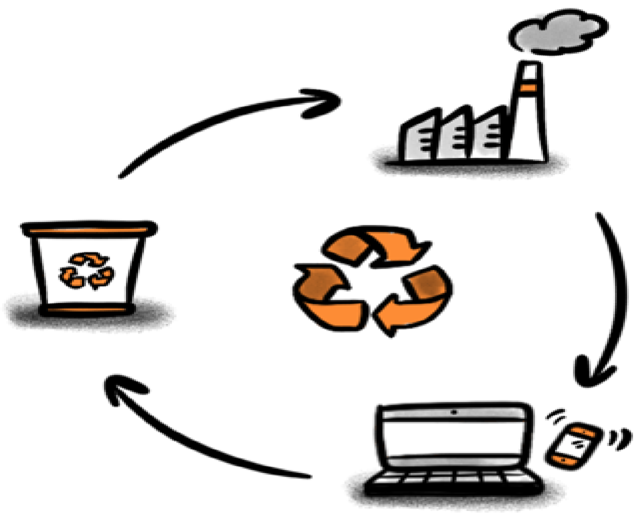
- **What is Waste-to-Energy?**

One type of energy recovery is known as a waste-to-energy process. In its most basic form, this type of recovery refers to any system that converts trash or rubbish into energy that may be utilized. These waste-to-energy solutions have the capability to transform several types of waste, such as gas, liquid, or semi-solid waste, into forms that may be utilized, such as heat, fuel for transportation, or power. It is not possible to recycle the waste material that is employed by waste-to-energy technology; thus, there is no alternative feasible option for the transformation of this waste material into a valuable resource. Recycling rubbish into energy that can be used is the specialty of businesses that specialize in waste-to-energy conversion.

The principal material source for waste-to-energy plants is municipal garbage, which is defined as the rubbish that cannot be recycled or composted but which is produced on a daily basis by all of us. This type of waste is produced in areas with a high population density. In this context, the term "municipal waste treatment" is an abbreviation for the method.

Despite the fact that incineration has been the method of choice for converting waste into energy (WtE) for a considerable amount of time, there are now a multitude of creative alternatives that provide more promise with less negatives, such as the toxic gasses that are generated by standard trash incinerators.

It is important to keep in mind that in order for waste-to-energy technologies to properly participate in a circular economy, it is essential to compost and recycle any rubbish that may be recycled. The concern that recyclable materials would not be recycled to the extent that they can be converted into energy is one of the most significant things that people have against waste-to-energy (WtE) facilities, which we shall go over in the later portions of this article.



- **Types of Waste-to-Energy Solutions**

Waste-to-energy systems can be classified as thermal simply (including incineration), thermo-chemical, mechanical and thermal, or biochemical, depending on the mechanism that is utilized to transform rubbish into energy. Incineration is included in this category.

Thermal WtE facilities are responsible for working with the vast bulk of MWT. Including anything that converts waste into useable energy by utilizing heat, this category encompasses everything that recycles rubbish. The incineration process, which was the first thermal waste-to-energy technique, is not a particularly good option for a variety of reasons, including high running costs and excessive emission rates. We should go back to the reason we got together in the first place, which was to investigate the most cutting-edge technology for converting garbage into energy.

- **Anaerobic Digestion (AD)**

The biochemical process known as anaerobic digestion includes placing food in a reactor that does not contain oxygen. This allows for the production of biogas and digestate without the presence of oxygen. Reactors that are stocked with a wide variety of microbial communities allow the waste to degrade.

Methane, which is also created by landfills but serves a useful function in this instance, is the principal component of the biogas that is produced by AD. Carbon dioxide is the other component that is produced by AD. In addition, there are trace amounts of water vapor, other gasses, and contaminants in the atmosphere.

Using biogas produced by anaerobic digestion, it is feasible to provide electricity, heat, and fuel for transportation. The digestate, which is another byproduct of the AD process, can be either a solid or a liquid. It has a number of possible applications, including the manufacturing of bio products such as construction materials and animal bedding, as well as the use of the digestate as a fertilizer.

- **Gasification**

As a result of the fact that the gasification process cleans the product (syngas) prior to its use, rather than after it has been utilized, it is generally considered to be a more effective thermal WtE method than incineration. Putting it another way, gasification waste-to-energy plants dramatically minimize the amount of air pollution that is produced in comparison to conventional incinerators.

When municipal waste is subjected to high temperatures, the process of gasification transforms it into syngas, which may then be used as a fuel alternative. The word "syngas" originates from the fact that it is a synthetic gas that is flammable and has several applications, such as serving as a substitute for natural gas, as a fuel for transportation, and as fertilizer. Due to the fact that gasification is not possible for all materials, it is essential to filter and pre-process municipal waste in a comprehensive manner before transferring it to a facility that specializes in gasification.

One of the numerous benefits of gasification is that it may be used to treat polymers that cannot be recycled without emitting any harmful gasses into the atmosphere. Plasma gasification, which is often referred to as plasma arc gasification, is the most recent development in the gasification process with regard to innovation.

- **Plasma Gasification**

Within the confines of a single reactor, the process of plasma gasification includes heating a plasma torch to extremely high temperatures (usually between 5,000 and 7,000 degrees Celsius, although the temperature can be lower or higher). Syngas, which mostly consists of hydrogen and carbon monoxide, is produced as a result of this process. Syngas may be produced from biomass, coal, municipal trash, or any other feedstock. Plasma pyrolysis is another name for plasma torching, which is a process that results in the breakdown of molecules and changes in the chemical makeup of the substance.

Gasification of plasma not only results in the production of valuable byproducts, but it also cleans syngas and makes use of it as a fuel source. As a consequence of the process, the slag that is left behind from the melted waste of plasma falsification is a substance that resembles glass and may be utilized as a construction material without any risks. No need to be concerned about potentially hazardous chemicals if you are! There have been instances in the past where plasma torches have been utilized to eliminate hazardous waste and chemical weapons.

Dioxins are still created after the syngas has cooled down, which is a very unfortunate aspect. In contrast, the amount of dioxins and furans that are created by traditional incineration plants is far lower than what is produced by these facilities. It should come as no surprise that this direction is the way ahead for waste-to-management technology, given that it is not only effective but also helps to reduce pollution.

Hydrothermal Carbonization (HTC)

A thermochemical process known as hydrothermal carbonization (HTC) has the potential to manufacture structured carbons such as fossil fuels, which would ordinarily take millions of years to develop. HTC uses wet feedstock in combination with an acid catalyst and pressure at temperatures ranging from 180 to 250 degrees Celsius in order to produce hydro-char, a product that has high carbon levels and is similar to fossil fuels. Hydro-char has the potential to replace coal in some applications, in addition to its potential as a fuel source. The most obvious benefit of this is that it allows one to avoid going through the myriad challenges that are connected with coal mining. The product has a number of potential applications, one of which is soil enrichment, and another is gasification, which is another application for the feedstock.

When compared to other thermochemical technologies, such as pyrolysis, HTC offers a significant advantage in terms of the speed with which it can process the feedstock without the need for pre-treatment or pre-drying. This is due to the fact that it was expressly designed to function with wet waste.

The conditions under which it operates are analogous to those under which anaerobic digestion will take place, and it generates the same amount of energy. HTC is able to take advantage of a shorter processing time in compared to other WtE processes, such as anaerobic digestion, and this is particularly advantageous. On the other hand, the majority of the environmental effects that this cutting-edge technology has yet to be uncovered are still relatively unknown. However, the findings of a recent study conducted in Germany revealed that the use of hydrochar as a fertilizer in lieu of NPK resulted in a significant amount of pollution. This was despite the fact that the study found that HTC is more ecologically benign than mono-incineration facilities for sewage sludge. The process of recycling waste into energy that may be used involves careful consideration of a number of different elements in order to find the most ecologically friendly techniques feasible.

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4

Air Pollution Control Strategies

Mrs. Rajbala*

Introduction

Carbon Offsetting

Carbon offsetting is a method that may be utilized by organizations to compensate for their greenhouse gas (GHG) emissions in the event that their GHG output is higher than their GHG consumption. Through the purchase of offset tokens, individuals have the opportunity to make a contribution to efforts that aim to reduce carbon emissions, such as forestry projects. Carbon-negative activities include a variety of technologies that provide improved soil management, industrial emissions traps, and energy-efficient integrations. These technologies all contribute to the reduction of carbon emissions. Through the purchase of carbon credits, individuals, corporations, and governments together have the ability to reduce the negative consequences of pollution. Additionally, full traceability and increased transparency are achieved through the utilization of cloud-based accounting and blockchain technology for carbon credit records. "Offsetting" refers to the practice of individuals and organizations donating to initiatives that decrease or eliminate emissions. This is one way that individuals and groups may do their part to alleviate the effects of climate change.

- **Abatable simplifies Carbon Intelligence & Procurement**

A company called Abatable, which was founded in the United Kingdom, offers a platform for the purchase and selling of carbon. The purchase of high-quality offsets for emissions that are difficult to reduce is made easier as a result of this, which enhances the social benefit of climate contributions. In order to shed light on the

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projects and the individuals who are responsible for them, the platform conducts an analysis of the important success criteria of carbon credit schemes. Abatable maintains a tight watch on all projects in order to decrease risks associated with infrastructure, processes, and rules. This is done in order to ensure that businesses really obtain carbon credits of the quality that was promised.

- **Tanso offers Automated Carbon Accounting**

Automating carbon accounting and providing analytical solutions for efficient emission reduction are two of the services that the German firm Tanso provides. Process automation, Excel/CSV uploads, application programming interface (API), and a single-source-of-truth approach are some of the ways that the software developed by the firm makes the process of data collecting and emissions computation more straightforward. Organizations are able to determine their carbon footprint and establish clear reduction objectives with the help of Tanso's methodology, which utilizes automated procedures and a single source of truth. This makes it possible to organize decarbonization measures, such as carbon offsetting and benchmarking, in accordance with goal criteria that are developed via scientific research.

Artificial Intelligence

The use of artificial intelligence enables businesses to gather and draw insights from vast volumes of data, as well as spot patterns that people either fail to perceive or take a long time to recognize. When firms have a more in-depth understanding of carbon emissions, they have a greater degree of agility to embrace technologies that reduce greenhouse gas emissions. This facilitates a more rapid and durable change while simultaneously lowering expenditures during a period of decreased cash flow. The environmental effect of emissions is also analyzed by solutions driven by artificial intelligence, and these solutions also give projections on storms, wildfires, and droughts, which enables better mitigation measures to be developed. In conclusion, artificial intelligence allows for the optimization of technology connected to carbon capture and renewable energy, which results in increased efficiency and decreased emissions.

- **AI Shading ensures Low Building Carbon Footprint**

For the purpose of assisting commercial buildings in meeting their emission reduction targets, AI Shading, a Canadian smart and green technology company, is developing solutions that are both cost-effective and efficient. Smart indoor shades, sensors, smartphone applications, and platforms for energy management are all components of the solution that were developed by the startup company to assist with this issue. Artificial intelligence shading gives building managers with information that might help them save energy, which enables them to more accurately evaluate energy use and monitor objectives for reducing emissions.

- **GAIA Provides Automated Emission Tracking**

The implementation of artificial intelligence (AI) by the Dutch company GAIA helps to expedite and automate the process of lowering greenhouse gas emissions for businesses. In order to assess and keep track of emissions, the startup's solution analyzes and monitors data from the input of choice, which may be either manual, linked, or integrated. The artificial intelligence algorithm makes use of the raw data in order to extrapolate in order to fill in any gaps in measurement or data. Within the framework of this strategy, the technology developed by GAIA is utilized to identify key sources of emissions and to enable the customisation of optimization plans and reduction objectives.

Electrification

Through the utilization of renewable electric power sources such as wind and solar, electrification contributes to the reduction of emissions that are produced by power plants that are powered by fossil fuels. This trend in pollution reduction solutions is being embraced by a wide variety of businesses, including the construction industry, transportation industry, manufacturing industry, and mining industry, amongst others. One further significant advantage of electrification is that it results in an increase in energy efficiency when compared to machinery that is powered by fossil fuels. This is in addition to the fact that clean power has a lower carbon intensity than conventional electricity. The process of electrification, which also enables demand flexibility, makes it feasible to distribute the available energy in a manner that is both beneficial and economical. As a consequence of the widespread adoption of electrification across a variety of industries, there is a significant reduction in emissions on a global scale.

- **Zevx accelerates Fleet Electrification**

In the United States of America, Zevx is a company that specializes in the development of data intelligence and battery electric power solutions for electric mobility. As a result of the products and powertrains that the company provides, commercial fleet assets are being electrified at a more rapid pace. Zevx's data intelligence services have resulted in a number of positive results, including enhanced operational efficiency and a more robust framework for managing power use. Through the integration of all operational components, the system provides fleet owners with a platform that allows them to decarbonize their operations.

- **Leaf Energy allows Seamless Energy Transition**

The electric vehicles (EVs) and charging stations that are offered by the American company Leaf Energy are examples of the electrification solutions that they provide. High-speed charging is made possible by the technology developed by the startup company utilizing its unique terminal designs, which are compatible with grid networks that are already in place. In addition to offering measurements for energy transition, Leaf Energy also provides a platform for real-time environmental tracking, which enables businesses to analyze their progress at each stage of the process.

Green Hydrogen

The electrolysis of renewable energy sources results in the production of hydrogen fuel, which does not result in the emission of greenhouse gases and only results in the waste of water. Hydrogen is a helpful substance in a wide variety of industries due to its chemical properties and high calorific value. Some of these applications include transportation, heating, and industrial processes. Clean hydrogen fuel cells are a game-changer in the transportation business because they make it possible to create vehicles that do not produce any emissions. In addition, it is a vital component in the production of low-carbon fuels and chemicals, which further contributes to the reduction of emissions from these industries. In order to combat climate change and reduce pollution, green hydrogen, which is a sustainable energy source, may be utilized.

- **Azolla generates Fuel-cell Spec Green Hydrogen**

An organization based in Canada called Azolla provides environmentally friendly hydrogen solutions to the transportation and electrical industries. By combining bio-methanol with deionized water, the startup's Biodrome technology is able to generate hydrogen that meets the specifications of fuel cells. This is accomplished at Azolla through the catalytic reformation of our bio-methanol/water mixture, which results in the production of low-carbon hydrogen on-site. In order to transport hydrogen, methanol can be utilized instead of high-pressure hydrogen or ammonia, which are both more burdensome chemicals. This is due to the fact that methanol is more convenient than either of these two substances.

- **Faraday Fuels offers Solid Oxide Electrolyzers**

Faraday Fuels, a clean technology company based in the United States, has developed a high-throughput solid oxide approach that has the potential to be scaled up in order to manufacture hydrogen that is sustainable for the environment. Solid oxide electrolyzers manufactured by the startup company have a tubular design and electrodes that have been patented in order to ensure the creation of pure hydrogen in an efficient and cost-effective manner. With this hydrogen, it is possible to decarbonize the steel, chemical, and aviation sectors, all of which emit a significant amount of carbon dioxide. This decarbonization process may be carried out in an efficient and effective manner.

Carbon Capture, Utilization, & Storage

By capturing carbon dioxide emissions with CCUS technology, it is possible to use these emissions in production or to permanently store them at depths of thousands of feet. In order to extract carbon dioxide, new businesses employ a wide range of techniques, some of which include the utilization of solvents and others of which involve membranes. The carbon monoxide that has been captured is either chemically or biologically concentrated in order to be used as a feedstock, or it is buried for later use. One of the most important aspects of CCUS is its capacity to maintain stable levels of carbon dioxide (CO2) in the atmosphere by reducing the concentration of this gas, which is caused by industrial activity. There are currently possibilities for feedstock that do not contribute to climate change that are available to the chemical industry, the oil and gas industry, the aviation industry, and the building industry. On the other hand, CO2 storage technologies make it feasible to access salt deposits, oil or gas reserves that have been depleted, or both of these resources.

- **Algiecel advances Algal-based Carbon Capture**

Modular photobioreactors are manufactured by the British company Algiecel. These photobioreactors make use of light-emitting diodes in order to generate oxygen and biomass from microalgae. Small, portable photobioreactors for microalgae and downstream units might be housed in standard shipping containers if the new company choose to employ them. Using this method, it is possible to generate a biomass that is abundant in food-grade omega-3 fatty acids, proteins, vitamins, and carotenoids from the CO2 emissions produced by industrial processes. Industrial firms have the ability to employ the carbon capture solution in this manner in order to reduce the amount of carbon emissions they produce and to open up a new source of income.

- **Aqualung achieves Absorbant-free Carbon Capture**

A Norwegian company called Aqualung is now working on developing a membrane separation system for carbon capture that is both incredibly small and does not require the use of absorbents. In comparison to conventional membranes, the solution developed by the company requires less energy since it eliminates the need for absorbents to engage in the process of regeneration. By avoiding the use of toxic chemicals or absorbents, it is also possible to limit the risks associated with operation and the costs associated with maintenance. The modular technology that Aqualung possesses makes it possible for carbon capture devices to be utilized in environments with low amounts of carbon monoxide.

Energy-Efficient Integrations

There is a significant amount of untapped potential in the usage of industrial excess energy, which has the ability to have beneficial impacts not just on enterprises but also on the majority of the population. Utilizing thermal energy, electrical power, and fuel, all of which are examples of surplus energy, is one method that may be utilized to reduce dependency on main energy sources. The emissions of carbon dioxide are lowered as a result of this. The most common methods of heat recovery include heating entering water and combustion air, as well as reusing waste heat for secondary processes that take place inside the facility. The recovery of pressure energy from high-pressure operations and the subsequent conversion of that energy into electricity through the utilization of pressure recovery turbines is yet another solution for power recovery. It is possible to apply this method to circumstances that include pressure fluctuations that are incredibly minute. The development of new materials and methods can help prevent the loss of energy and minimize emissions. Additionally, there are technologies available that can recover energy that has been squandered.

- **Sapphire Technologies simplifies Excess Pressure Energy Recovery**

In the United States of America, Sapphire Technologies is a startup firm that is developing energy recovery devices to create clean and reliable electricity from expanding gas. During pressure reduction processes, the FreeSpin In-line Turboexpander Generator of the startup company converts the energy that would otherwise be wasted into power. This is accomplished without hindering the operations of the business. The solution provided by Sapphire Technologies is capable of satisfying the industrial applications of hydrogen and natural gas. It is able to achieve monetary returns while simultaneously maximizing efficiency, boosting productivity, reducing carbon emissions, and balancing the costs of power.

- **HT Materials Science facilitates Efficient Heat Transfer**

HT Material Science, an Irish company, offers heat transfer fluids made specifically for use in commercial and industrial heating, ventilation, and air conditioning (HVAC) systems. The startup's patented nanofluid additive Maxwell is a drop-in solution that enhances the efficiency of HVAC systems. It does this by increasing the heat transfer of a base refrigerant. It is possible to achieve a reduction in carbon emissions that is proportional to the reduction in energy consumption as a result of this. A further gain in operational sustainability is achieved as a result of the higher heat transfer rate, which allows for the utilization of machinery that is more compact, less expensive, and more efficient.

Big Data

Big data may be utilized by businesses in order to identify specific regions in which they are consuming an excessive amount of energy and creating an excessive amount of carbon emissions. The utilization of energy in a more efficient manner and the implementation of actions to minimize emissions are both facilitated by this knowledge. In order to gather operational data from the past, these systems collect data from emission sensors and smart energy devices that are dispersed across communities and buildings. By evaluating data on energy use, businesses have the opportunity to improve their energy efficiency and identify patterns in energy consumption. By analyzing transportation routes, inventory levels, and delivery schedules, big data solutions also assist in optimizing the supply chain. This, in turn, helps to decrease the carbon footprint that is produced by items traveling longer distances. In conclusion, companies determine the most effective times to utilize renewable energy sources by analyzing data on energy consumption and efficiency. It is possible for them to decrease the influence that they have on the environment by decreasing the amount of non-renewable resources that they utilize.

- **Grid Matrix aids Transport Emission Reduction**

A software company called Grid Matrix, which was founded in the United States, claims that it can solve problems like as traffic congestion, pollution, and accidents by utilizing the infrastructure that is already in place. The cloud-based platform of the new company merges data from pre-existing sensors with data from online sources. This is accomplished through the utilization of big data and analytics. After that, it contributes to the optimization of mobility services by delivering real-time insights that are generated from the data that was obtained. It is possible for cities to make greater progress toward their transportation objectives, developing into communities that are more effective, less harmful to the environment, and safer as a consequence. Because of this, congestion and emissions of carbon gases are consequently eliminated.

- **CarbonSense simplifies Carbon Footprint Management**

CarbonSense is a Chinese company that develops a software solution that serves the purpose of assisting enterprises in achieving carbon neutrality. Big data techniques are utilized by the green management system of the company with the purpose of gathering and analyzing data pertaining to energy. The information contained in this report originates from a variety of sources, such as smart meters, water meters, gas sensors, temperature sensors, and equipment PLC. The procedure results in a number of discoveries, some of which include the visualization of energy consumption, the multi-dimensional analysis of energy consumption, the research of equipment efficiency, and the early alerting of anomalies in equipment. These insights set the stage for intelligent decisions that will cut down on the amount of electricity that is consumed and speed up the transition to renewable energy.

Waste Valorization

The process of waste valorization allows for the upcycling of products that have reached the end of their useful life as well as the reduction of carbon emissions. The transportation of waste away from landfills is directly responsible for the reduction of emissions of methane, which is a potent greenhouse gas. In addition to lowering emissions of greenhouse gases that are caused by the production of energy, waste valorization results in the generation of low-carbon energy such as biogas or biochar, which can serve as a replacement for fossil fuels. Through the process of recycling waste materials into new products, it may be possible to further reduce the generation of greenhouse gases and the need for new resources. Last but not least, the utilization of waste valorization techniques that capture and make use of carbon dioxide emissions has the potential to facilitate the development of a circular carbon economy and help lessen the negative effects on the environment.

- **Alimentary advances Domestic Waste Valorization**

Alimentary, a firm based in New Zealand, is all about an integrated waste treatment plant (IWTP) that is capable of managing any kind of organic waste. The novel waste treatment method that was created by the company is adaptive to the particular waste sources in the region and makes use of a combination of biomimicry and anaerobic co-digestion. This makes it possible to save a substantial amount of money on waste disposal. When wastewater and household garbage are treated, the amount of greenhouse gases that are released into the environment is reduced. This is because of the treatment process. Additionally, the valuable byproduct of biogas enables the generation of money, which in turn pays expenditures.

- **Pyro-degrade facilitates Plastic Waste to Fuel Conversion**

In order to convert waste plastic into fuel, a company in Kenya known as Pyro-degrade has invented a method known as pyrolysis. The startup's fuel is referred to as pyro-diesel, and it is an environmentally friendly alternative to diesel that is low in carbon effect and does not include sulfur. As an additional benefit, the organization is able to run independently of the grid by utilizing the fuel that it generates because the technology that it uses is self-sufficient. In addition to minimizing the open burning of plastic rubbish, this innovation provides a low-carbon alternative to diesel that can be used for farming and other home duties. It also gives the possibility of using fuel for other purposes.

Bio-based Fuels & Polymers

The use of bio-based solutions makes it feasible to reduce emissions since they provide long-term alternatives to fossil fuels and other chemicals that are hazardous to the environment. The production of biofuels such as biodiesel and bioethanol, which are made from renewable plant-based components, has the objective of reducing emissions to the greatest extent possible. The traditional plastics that are created from petroleum are replaced with biopolymers, which are made from natural fibers and resins. Biodegradable plastics are an example of this. The use of waste materials and by-products in the production of biopolymers and biofuels is yet another method that may be utilized to lessen the amount of trash and emissions that are produced as a result of waste management. By utilizing biofuels and biopolymers, which provide sustainable alternatives to conventional energy sources and construction materials, it is possible to lessen emissions and contribute to the development of a more environmentally friendly future.

- **SeaH4 produces Carbon-Neutral Fuels**

SeaH4, a clean technology business based in South Africa, provides solutions that make it possible to earn a profit from the production of environmentally friendly biodiesel and liquefied natural gas (LNG) from algae. The new business venture makes use of fundamental technologies such as the cultivation of algae on land, the generation of biogas, the processing of gas, and the transformation of gas into liquid. SeeH4's technology is completely circular, which reduces the amount of money spent on operations while simultaneously yielding more. The final fuel product makes it possible for combustion engines to operate without producing carbon dioxide, which speeds up the process of transitioning away from fossil fuels.

- **Dionymer offers Petrochemical Plastic Alternatives**

The French firm Dionymer is working on developing a material technology that recycles organic waste from industrial processes. The fermentation technique that is exclusive to the firm involves a biomimetic process that converts organic waste into polyhydroxyalkanoates (PHA), which are a biodegradable polymer substance. Polymer compounds like this can be used as low-carbon alternatives to plastics made from petrochemical reactions. Additionally, the technique offers a recovery path for bio-waste across industries such as agriculture and medicines, which is a significant benefit in addition to lowering carbon emissions.

Emission Monitoring

Emission monitoring and management contributes to the reduction of emissions by providing businesses with the ability to monitor their emissions and identify areas in which they may reduce their emissions. The objective of a monitoring system is to gather information about the amounts of emissions taking place in real time by identifying emissions coming from a number of different sources. Through the process of analyzing and making sense of this data, management systems are ultimately able to assist organizations in discovering strategies to make reductions in emissions. By managing and monitoring emissions on a consistent basis, organizations have the capacity to improve their sustainability, reduce their impact on the environment, and remain within the boundaries of the existing regulatory restrictions. In addition to this, businesses are increasingly employing a comprehensive and well-organized plan in order to regulate, monitor, and cut down on emissions. With this, they are able to achieve their goals of reducing emissions and operate in a manner that is carbon neutral.

- **GAIT delivers Greenhouse Gas Measurement**

The climate technology solutions that are offered by GAIT, a company based in Singapore, make it simpler to set up equipment for detecting greenhouse gas emissions. Geographical data, flux sensors, and machine learning are all components that are included into the system that the company has built in order to deliver real-time measurements of greenhouse gas emissions. By utilizing historical flow data, it is also possible to construct more accurate models for evaluating the effectiveness of climate action measures. Additionally, the solution stipulates the actions that must be taken in order to achieve the air quality objectives and reduce emissions even further.

- **Blue Sky advances Fugitive Methane Emission Detection**

Through the utilization of infrared optical sensors, the American company Blue Sky is now working on a technology that will enable continuous detection and monitoring of fugitive methane emissions. NIR view, the emission monitoring system that the firm provides, employs a method that is based on spectroscopy to automatically scan a grid that the user sets and provide a detailed two-dimensional concentration map. By utilizing this strategy, the oilfields may be able to take advantage of a leak-location detection system that is not only inexpensive but also enables speedy repairs and significantly reduced emissions.

Air Quality Monitoring

When we talk about monitoring air quality, we are referring to the process of collecting and measuring samples of ambient air pollution. It is possible to establish the status of the air by comparing the data from these samples to clean air standards and historical information regarding air quality levels. Additionally, data representing the consequences of the air on both human health and the environment are also taken into consideration.

Types of air quality monitoring systems:

When it comes to monitoring air quality, there are several levels of government involved, including the federal, state, regional, and local levels. The fact that air quality may vary significantly even between geographical locations that are situated in close proximity to one another highlights the need of establishing a reliable network for detecting air pollution that can give data on air quality on a regional and smaller scale. In most cases, the national air quality monitoring network is made up of reference-grade monitors that are located at the federal level. Networks set up at the state level monitor the levels of air pollution. More than 250 stations are dispersed around the state of California as part of the network that monitors the quality of the air in the surrounding environment.

The following objectives have been established by the California Air Resources Board (CARB) for the air quality monitoring system that will be implemented throughout the state:

- Please explain the reasons of the state's air pollution as well as the severity of the problem.
- In order to determine whether or not the Ambient Air Quality Standards have been satisfied, it is necessary to conduct an assessment of the air quality.
- Analyze the patterns that emerge in the quantities of pollutants.
- Make sure that the statistics on the air quality are kept up to date all the time.
- It is important to determine the amount to which inhabitants are exposed to potentially harmful substances.

It is necessary to establish air quality monitoring districts in order to keep track of the levels of pollution in the surrounding area and to put in place restrictions that are suitable.

One air quality district, the Monterey Bay Air Resources District (MBARD), utilized low-cost sensors to supplement their existing monitoring network in order to address issues related to air pollution, such as the impacts of smoke from wildfires. By doing so, they were able to supply its communities with a greater quantity of real-time data.

On the other hand, there are a great number of counties and areas that do not get sufficient monitoring of the air quality. This is a significant issue because significant pollutants such as PM2.5 have the potential to cause harm to both people and the environment. According to the Environmental Protection Agency (EPA), in 2019, 2,120 out of 3,142 counties in the United States did not have any ambient air quality monitoring infrastructure that was linked to the national monitoring system. Because of this, it is of the utmost need to establish local monitoring networks in order to cover the regions where the monitors that are already in place are insufficient.

Parameters that are measured in air quality monitoring:

In accordance with the nationwide Ambient Air Quality Standards (NAAQS), the Environmental Protection Agency of the United States monitors six criteria pollutants on a nationwide level:

- Ground-level ozone
- Particulate matter
- Carbon monoxide
- Lead
- Sulfur dioxide
- Nitrogen dioxide

It is also a matter for concern because there are pollutants that have been confirmed or believed to have carcinogenic properties, as well as those that contribute to other serious health implications; these pollutants are referred to as air toxics. One example of an air hazardous is benzene, another is mercury, and still another is arsenic.

Types of air quality monitoring stations:

A variety of various technologies may be utilized in order to monitor the quality of the air.

The federal reference method (FRM) and the federal equivalent method (FEM) are two types of equipment that are widely utilized by government agencies in order to monitor the levels of air pollution at certain locations. For the purpose of monitoring FRM and FEM networks, the United States Environmental Protection Agency collaborates with local and state governments in the United States.

Near-reference monitors are a form of air quality monitoring equipment that are less expensive than regular reference-grade monitors while yet delivering high-quality data. The phrase "near-reference monitors" denotes this sort of measurement instrument. Near-reference displays are calibrated with reference-quality equipment, which is employed for the calibration process. It is possible to assess environmental factors such as temperature and humidity, as well as particular pollutants such as particulate matter and nitrogen dioxide, using sensors that are not prohibitively expensive. High-resolution data may be collected by low-cost sensors at higher densities than by reference-grade equipment. This is possible because low-cost sensors are less expensive than reference-grade equipment. There are air quality sensors that are both stationary and mobile in nature.

The goal of stationary monitoring is to collect data on air pollution at specified sites. These locations may be in close proximity to other sources of pollution, such as businesses or busy highways, or they may be in areas where air pollution is particularly severe. By affixing air pollution measuring devices to cars, it is possible to conduct mobile air quality monitoring, which in turn makes it possible to carry the equipment to other locations. technology is not always possible for mobile monitoring to identify specific trends, hotspots, or spikes in pollution, despite the fact that technology makes it possible to collect data on air quality across a greater territory in a shorter amount of time.

Mobile air quality monitoring, which is comparable to the use of affordable sensors, is widely deployed in conjunction with reference-grade monitors. By linking mobile monitoring equipment to global positioning system (GPS) systems, we are able to precisely locate the whereabouts of air pollutants and examine the temporal fluctuations of these contaminants.

Why is air quality monitoring important?

Due to the fact that poor air quality can have a wide variety of negative effects, it is especially important to monitor the air quality and have an awareness of the exposure levels.

Additionally, it has been established that climate change is closely connected to air quality, and that addressing some sources of air pollution may have the potential to assist in mitigating the impacts of this global warming.

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5

Sustainable Agriculture and Agrochemicals

Dr. Anita Malav*

Introduction

Eco-Friendly Pesticides and Fertilizers

- **Biological Pesticides**

Pesticides that are derived from living species, such as plants, animals, microbes, and even minerals, are referred to as biological pesticides or biopesticides. They are considered to be more environmentally benign than conventional pesticides due to the fact that they are more selective in the pests that they target and do less harm to animals, people, and insects that are useful to the environment.

- **Microbial Pesticides**

One of the active components of a microbial pesticide is a microbe, which can be a bacterium, fungus, virus, or protozoan, among other similar organisms. They are quite selective, as evidenced by the fact that they prefer to target just the pest of interest as well as other organisms that share a similar biological makeup. Bacillus thuringiensis, sometimes known as Bt, is one of the most well-known microbial pesticides. It has demonstrated effectiveness against a wide variety of insects, including fly larvae, beetles, and caterpillars, among others.

- **Biochemical Pesticides**

All of the substances that are included in biochemical pesticides are those that control pests through mechanisms that are not poisonous. Pheromones, which hinder insects from mating, and a range of aromatic plant extracts, which attract insect pests to traps, are both included in this category of substances. Because of their specific

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modes of action and their natural origin, these chemicals are less damaging to the environment and creatures that are not the intended targets of their effects.

- **Plant-incorporated Protectants**

Plants, together with the genes that are responsible for their production, synthesize pesticides that are referred to as plant-incorporated protectants (PIPs). Through the use of biotechnology, researchers have the ability to design plants to possess desirable characteristics, such as resistance to pests, by adding a gene related to that characteristic. There is a possibility that the succeeding GMO crops may drastically reduce the amount of chemical pesticides that are used.

Botanical Pesticides

Plants that are recognized to have insecticidal characteristics are the source of botanical pesticides, which are compounds that occur naturally and are derived from plants.

- **Neem Oil and Other Plant Extracts**

Neem oil, which is collected from the seeds of the Azadirachta indica tree, has a wide range of compounds that have the ability to kill insects and provide medicinal benefits. Over four hundred different species of insects are affected by it, and it acts as a deterrent, a repellent, and an anti-feedant.

- **Essential Oils as Natural Insecticides**

Researchers have investigated the possible insecticidal and repellent effects of essential oils, which are concentrated liquids that include volatile fragrance components originating from plants. Essential oils have attracted the attention of researchers. Essential oils derived from plants, such as peppermint, eucalyptus, and citronella, have been shown to be effective in warding off a wide range of pests.

Mineral Pesticides

Mineral pesticides comprise inorganic substances that control pests.

- **Diatomaceous Earth**

Diatomaceous earth is a fine powder that is formed from the fossilized remnants of diatoms, which are hard-shelled algae. Diatom seeds are used to manufacture diatomaceous earth. In addition to being able to kill insects, it may also dehydrate them. There are many different kinds of insects that it is effective against, including cockroaches and bed bugs, amongst others.

- **Sulfur and Other Minerals**

Because it is effective against both mites and fungi, sulfur is considered to be one of the oldest pesticides that have ever been discovered by humans. Copper and other minerals have been used by farmers for many years as fungicides and bactericides since the beginning of time.

Types of Agricultural Fertilizers

- **Organic Fertilizers**
    - **Compost:** Additionally, the presence of degraded organic matter contributes to an improvement in the soil's structure, as well as its nutritional content and water retention.
    - **Manure:** Composting animal manure in the appropriate manner results in the addition of organic matter and essential nutrients to the soil.
    - **Bone Meal:** A phosphorus-rich fertilizer that is created from shattered animal bones that gradually releases its nutrients into the soil.
- **Biofertilizers**
    - **Rhizobium and Mycorrhizal Fungi:** Through the establishment of symbiotic relationships with plant roots, these beneficial microorganisms are able to enhance the plant's ability to absorb nutrients and to maintain overall health.
    - **Azotobacter and Azospirillum:** In order to promote plant development, microbes that fix nitrogen from the atmosphere and then release it to plants.
- **Fish Emulsion**
    - A liquid fertilizer that is created from fish waste and is rich in nitrogen as well as other important ingredients.
- **Algae-based Fertilizers**
    - Derived from seaweed or algae, these fertilizers provide a range of nutrients, improve soil structure, and stimulate plant growth.

Natural Mineral Amendments

- **Rock Phosphate:** A slow-release source of phosphorus.
- **Gypsum:** Adds calcium and sulfur without altering soil pH dramatically.

- **Biochar**
    - Charred plant material that improves soil structure, water retention, and nutrient availability.

Amino Acid-based Fertilizers

- Derived from plant or animal proteins, these fertilizers provide nitrogen in a form readily available to plants.

- **Slow-release Fertilizers**
    - These formulations break down slowly, providing a sustained release of nutrients to plants and reducing the risk of leaching.

Precision Farming

Precision agriculture, sometimes known as PA, is a kind of agricultural management that focuses on monitoring and responding to the variability of crops both within and between fields. Agricultural practices are referred to by a number of various names, including as-needed farming, precision agriculture, satellite agriculture, and site-specific crop management (SSCM).

By precisely targeting the nutritional requirements of crops and soils with the use of information technology (IT), the objective of precision agriculture is to achieve the highest possible levels of crop and soil health and productivity. This ensures that all three of these things—profitability, sustainability, and environmental protection—will be achieved. When managing crops, it takes into consideration a variety of aspects, such as the kind of soil, the location, the weather, the development of the plant, and the yield statistics.

How does Precision Agriculture Work?

The foundation of precision agriculture is comprised of specialized elements like as hardware, software, and information technology services. This includes the capability to get up-to-the-minute information on the status of the crop, the soil, and the air, as well as hyperlocal weather predictions, labor rates, and the availability of equipment.

Providing real-time data, sensors that are put in fields detect the moisture content of the soil as well as the temperature of the air. In addition, satellites and robotic drones may be able to supply farmers with live photographs of certain plants.

What are the Benefits of Precision Agriculture?

Farmers are provided with recommendations for soil management, planting and harvesting dates, and crop rotation on the basis of the data that is collected and subsequently utilized by predictive analytics software.

Farmers are able to detect which fields require treatment and calculate the optimal quantities of water, fertilizer, and pesticide to apply with the assistance of agricultural control centers. This is accomplished by merging the data from a variety of sensors with imagery contributions.

By doing so, the farmer is able to keep costs low and the environmental impact of the farm under control. This is accomplished by preventing the waste of resources and runoff, as well as by ensuring that the soil receives the appropriate quantity of additives to ensure its optimal health.

What are the use Cases for Precision Agriculture?

When it came to the capacity to fully implement and reap the benefits of precision agriculture, it was previously only available to larger firms who had the financial means to purchase the required information technology infrastructure and other technical resources.

However, with the assistance of cloud computing, artificial intelligence sensors, drones, and smartphone applications, even the smallest family farms and cooperatives are now able to engage in precision agriculture.

These days, precision agriculture is utilized for a variety of purposes, including but not limited to:

- **Agricultural mapping and field scouting.** Field maps that have a high degree of detail can be created using drones equipped with cameras. Through the utilization of this data, problems may be identified, crops can be monitored, and the potential for production can be evaluated.
- **Soil sampling and analysis.** It is possible to collect data on a variety of soil properties using mobile apps. These factors include fertility, moisture content, and type. This information may be used to contribute to the formulation of decisions on crop management measures such as irrigation and fertilization.
- **Weather monitoring.** The utilization of hyperlocal meteorological data makes it possible for users to make decisions about planting schedules, watering requirements, and harvesting timings that are more informed.
- **Labor management.** The presence and activities of field workers may be tracked through the utilization of mobile applications that are equipped with GPS capabilities. This data has the potential to improve workflows as well as the efficiency of work.
- **Equipment management.** It is possible that agricultural machinery is rather expensive. Through the use of precision agriculture, farmers are able to simply monitor their machinery, prepare for planned maintenance, and predict any issues.

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6

Thermal Study of New Synthesized Complexes With Schiff Base Ligand

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Introduction

We report here series of new the Schiff base ligands having general composition. The Schiff base ligands were characterized on the basis of analytical conductance, molecular weight and spectral studies. The Schiff base behave as neutral monodentate ligand which coordinate to the central metal atom through azomethine nitrogen Schiff base ligand used for complex formation were synthesized in laboratory. Schiff bases formed by different aldehydes are in wide use for the synthetic purpose in both organic synthesis and in co-ordination chemistry of metal complexes. These are reported as stable compounds which are in use as a ligand for synthesis of various complexes. Schiff bases formed by 4-NN-BIS 2'-cyano ethyl amino benzaldehyde and 2-Methyl-4-NN-BIS 2'-cyano ethyl amino benzaldehyde have been reported to form stable complexes with metals. Experimental data for some of these schiff bases are available. The theoretical studies were done for schiff bases formed by is aldehydes with varying amines to locate and confirm the site for co-odination of the compounds to metal on the basis of electronics structure of the schiff bases.

General Procedure of Schiff bases Ligands

The aldehyde (~1m.mol.) and p-toudine (~1.1m.mol.) were taken in a round bottom flask, to which two drops of piperidine were added. The contents were heated for four hours in an oil bath maintained at 100-105^{o}C. The contents first melted and then solidified. The Schiff base was purified by recrystallization from ethanol as yellow solid with sharp melting point.

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Other Schiff bases of p- toludine, and aniline were synthesized by the aforesaid procedure.

Schiff base ligands (I-i) used for complex formation were synthesized in laboratory.

4-NN-bis-2'-cyanoethylaminobenzylidene p-toludine [4-CABPT]

2-Methyl-4-NN-bis-2'-cyanoethylaminobenzylidene p-toludine. [2-MCABPT]

Thermal Studies for Complexes: Thermogravimetric analysis (T.G.A.) of the complexes were recorded on thermo-balance Mettler Toledo Star system at the rate 10^0c/min. at Regional Sophisticated Instrumentation. The rate of loss of mass vs temperature (DTG) plots were used as TGA curves. The decomposition data for the complexes are in corporated Tables 1-2

- **Thermal Decomposition Kinetics Studies:** Freeman-Carroll (F.C.) [21], Coats-Redfern (C.R.) [22] and Horowitz-Metzger (H.M.) [23],methods were used to evaluate different kinetics parameters from the TGA curves as furnished in Tables 1-2.The corresponding kinetics parameters are given in Tables 1-4. **Table. 1: Thermal decomposition data for -4-NN-bis-2'-cyanoethylaminobenzylidene p- toludine complex with thorium (IV)nitrate.**

Complex	Stage of Decomposition	Reaction	Peak Temp. in DTG (^{0}C)	Temp. Range in DTG (^{0}C)
$Th(NO_3)_4$. 4 (4CABPT)	I	$Th(NO_3)_4$.4(4CABPT)→$Th(NO_3)_4$. 3.6(4CABPT)	243	221-274
	II	$Th(NO_3)_4$3.6(4CABPT)→$Th(NO_3)_4$. 3.1(4CABPT)	421	428-443
	III	$Th(NO_3)_4$.3.1(4CABPT)→$Th(NO_3)_4$. 1.66(4CABPT)	554	533-600
	IV	Th $(NO_3)_4$. 1.66(4CABPT)→ ThO_2	700	680-720

Table 2: Thermal decomposition data for 2-Methyl -4-NN-bis-2'-cyanoethylaminobenzylidene p- toludine complex with thorium (IV)nitrate

Complex	Stage of Decomposition	Reaction	Peak Temp. in DTG (^{0}C)	Temp. Range in DTG (^{0}C)
$Th(NO_3)_4$. 4 (2MCABPT)	I	$Th(NO_3)_4$.4(2MCABPT)→$Th(NO_3)_4$. 3.6(2MCABPT)	240	223-270
	II	$Th(NO_3)_4$3.6(2MCABPT)→$Th(NO_3)_4$. 3.1(2MCABPT)	418	428-442
	III	$Th(NO_3)_4$.3.1(2MCABPT)→$Th(NO_3)_4$. 1.66(2MCABPT)	545	533-580
	IV	Th $(NO_3)_4$. 1.66(2MCABPT)→ ThO_2	688	690-728

Freeman-Carroll (FC) method: Freeman-Carroll had proposed a method for the evaluation of kinetic parameters using an equation which is represented as

$$\frac{-dx}{dt} = A \exp\{-E^*/RT\}X^n \qquad \ldots\ldots(1)$$

Where the symbols have their usual meanings, for the general equation:

aA→ bB + cC

Equations (1) have been solved by the authors [21]. The results have been used to study reaction kinetics in the form of:

$$\frac{-E^*/2.303\,R\,(\Delta T^{-1})}{\Delta \log Wr} = -n + \frac{\Delta \log (dw/dt)}{\Delta \log Wr} \qquad \ldots\ldots(2)$$

Where Wr = Wc – W

Wc = weight loss at completion of the reaction and

W = weight loss up to time t

Equation (2), suggests that on plotting

$$kl\ \frac{\Delta \log(dw/dt)}{\Delta \log Wr} \quad Vs \quad \frac{(\Delta T^{-1})}{\Delta \log Wr} \qquad \ldots\ldots.(3)$$

For the decomposition reaction, order 'n' can be obtained as intercept of the linear graph and E*/2.303 as slope from where E* can be computed.

On applying this equation to the thermal data for representative thorium (IV) and dioxouranium (VI) complexes it was inferred that the thermal reactions which are mentioned in Tables 1-4 are of order unity. E* values, for each were evaluated from the slopes of the Freeman-Carroll plots which are furnished in Tables 5-8.

Coats–Redfern (CR) method: For the study the kinetics of thermal decomposition reactions, another method, was proposed by Coats and Redfern [22]. These author had given some relations among α the fraction of compound at time 't' and some other parameters to study the kinetics. The relations are:

$$\log\left\{\frac{1-(1-\alpha)^{1-n}}{T^2(1-n)}\right\} = \log\left\{\frac{AR}{\alpha E} * \left(\frac{1-2Rt}{E^*}\right) - \frac{E^*}{2.3RT}\right\}$$

for n/= 1 .....(4)

and $\log\left\{\frac{-\log(1-\alpha)}{T^2}\right\} = \log\left\{\frac{AR}{\alpha E} * \left(\frac{1-2Rt}{E^*}\right) - \frac{E^*}{2.3RT}\right\}$

for n = 1 .....(5)

Where α is fraction of the compound at time 't' and it is equal to $(W_0\text{-}W)/(W_0\text{-}W_f)$

Where W_0, W and W_f are initial weight, weight at time 't' and the final weight of the sample respectively and 'a' is the rate of heating. Other symbols have usual meanings.

These equations were applied to the decomposition reaction of the selected complexes and it was observed that the plots of

$$\log\left[\frac{-\log(1-\alpha)}{T^2}\right] \text{ Vs } 1/T$$

are straight lines. This justifies that these reactions may have order unity (i.e.n=1) as observed on the basis of Freeman-Carroll method. E*values for these are obtained from the slopes of Coats-Redfern plots as (-E*/2.3R) and 'A' from the intercepts of the plots.

ΔS^* values for the reactions are obtained from the following equation

$$\Delta S^* = R \ln \{Ah/kTs\} \qquad \text{.....(6)}$$

Horowitz-Metzger (H.M.) Method

Horowitz-Metzger method is an illustrative of approximate method. The authors derived a relation for first order thermal reactions which may be written as:

$$\log\{\log W\alpha/Wr\} = \frac{F^*\theta}{2.3RT_s^2} - \log 2.3 \qquad \text{......(7)}$$

Where θ=T-T_s and T_s is the peak temperature and dw/dt is maximum in the DTG curve.

In the present study the approximation method was tried to the representative complexes.

It was observed that the plots of log {log (Wα/Wr)} vs θ are straight lines. E* for these thermal decomposition reactions are calculated from the slopes of these plots and A is calculated using the following equation

$$\frac{E^*}{RT_s^2} = \frac{A}{a\exp\{-E^*/RT_s\}} \qquad \text{......(8)}$$

The results of kinetics parameters are incorporated in Tables 5-8.

In the concluded that the values of E*, A and ΔS^* are appreciable and E* values are sufficiently high while ΔS^* have negative values. The values are comparable with previous observations.

Horowitz-Metzger method gives [23] reasonably good results but it is mathematically less accurate than the integral methods. Coats- Redfern method seems to be more accurate but considerably time consuming.

Table 3: Decomposition kinetics parameters of complex $Th(NO_3)_4$.4(4CABPT) obtained using equations of Freeman Carroll (FC) Coats Red fern (CR) and Horowitz-Metzger (HM)

Complex	Decomposition Stage	Equation	Parameters		
			E*(KJMol^{-1})	A(S^{-1})	ΔS*(JK Mol^{-1})
$Th(NO_3)_4$.4 (4CABPT)	I	FC CR HM	34.15 37.11 40.82	- 7.37×10^4 6.38×10^4	- -52.67 -43.36
	II	FC CR HM	21.18 29.31 31.13	- 1.91×10^4 1.78×10^4	- -66.64 -58.46
	III	FC CR HM	26.28 29.12 35.23	- 9.81×10^5 8.91×10^5	- -125.60 -130.06
	IV	FC CR HM	34.84 36.45 45.82	- 3.30×10^4 3.19×10^4	- -137.61 -111.16

Table 4 : Decomposition kinetics parameters of complex $Th(NO_3)_4$.4(2MCABPT) obtained using equations of Freeman Carroll (FC) Coats Red fern (CR) and Horowitz-Metzger (HM)

Complex	Decomposition Stage	Equation	Parameters		
			E*(KJMol^{-1})	A(S^{-1})	ΔS*(JK Mol^{-1})
$Th(NO_3)_4$.4 (2MCABPT)	I	FC CR HM	37.11 39.41 45.92	- 7.37×10^4 6.38×10^4	- -54.68 -45.36
	II	FC CR HM	22.13 26.31 38.13	- 1.91×10^4 1.78×10^4	- -63.64 -59.46
	III	FC CR HM	23.22 29.12 33.21	- 9.81×10^5 8.91×10^5	- -135.60 -140.06
	IV	FC CR HM	36.84 39.48 42.84	- 3.30×10^4 3.19×10^4	- -127.61 -121.16

Results and Discussion

The computed heat of formation, total energy, electronic energy, core-core repulsion energy, ionization potential and other computed results on the basis of AM1 and PM3 methods are given in the table 1. For any ligand, to be used for stable complex formation, it is the most common requirement is to locate the bonding site, with which the metal ion will react. In this regard, the net atomic charge and the atomic electron density become useful parameter to look for the co-ordination site of a ligand and the stability of the complex.

Same observation one can draw if have a look on the net atomic charges on the azomethine nitrogen atom, it is highly negative in value as compared to other atoms of theses schiff bases. The net atomic charges are in the range - 0.0109 to - 0.2637 for N-atoms (azomethine) Both of these facts support that in these schiff bases the high electron density is there on the azomethine nitrogen and it posses a high negative net atomic charges. So0, it can co-ordination of (-C=N-1) to the thorium (IV) metal atom via azomethine nitrogen atom [18]

it is clear from the above discussion and the values obtained for various parameters for this compound that this can be use as effective (-C=N-1) azomethine ligand towards the metals for forming stable metal complexes. On the change of position of methyls group in the phenyl ring, there is some change in the net atomic charge and electron density on the nitrogen atom of the (-C=N-1) azomethine group even then the electron density values are high on the azomethine nitrogen and high negative charge on these nitrogen suggest that these schiff bases would prove to be effective ligands.

Conclusion

The quantum chemical calculation can be successfully used to prodict the stability of the complex and making more active ligands, used for complex formation which may be work of interest for co-ordination and bioinorganic chemists, as it is discussed here for a schiff bases. For any ligand, to be used for stable complex formation, it is the most common requirement is to locate the bonding site, with which the metal ion will react. In this regard, the net atomic charge and the atomic electron density become useful parameter to look for the co-ordination site of a ligand and the stability of the complex.

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7

Renewable Energy and Chemical Innovations

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Introduction

Biofuels and Bioenergy

The term "biofuel" refers to a fuel that is both limitless and biodegradable, and it is produced from biomass.

It is generally agreed that biofuel is the most unadulterated and readily available fuel on the planet. Biofuels are derived from biomass, which includes things like wood and straw. These biofuels are produced by the direct burning of dry materials, which creates a gaseous and liquid fuel at the same time. Other sources include organic matter such as sludge, sewage, and vegetable oils matter, which may be turned into biofuels by a wet process such as digestion and fermentation. Other sources include sewage and biomass.

Types of Biofuels

The majority of fuels that fall under the category of biofuel are readily available in every region of the world.

- It is biodiesel,
- Bioethanol
- A bio-based ethanol product

In today's world, the two types of biofuels that are utilized the most frequently are biodiesel and bioethanol. Both of these are examples of the initial work that was done in the field of biofuel technology.

Production of Biofuel from the Plant Products

One method of producing energy is by burning materials such as wood, straw, and rubbish from the home. There are a variety of additional possible sources of biofuels, including animal fats, plant leftovers, and alternative organic wastes.

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This process may be broken down into three primary components:

- **The First Generation of Biofuels:** This type of biofuel is produced by cultivating edible crops such as sugar cane, starch, and other food crops on arable land.
- Plant materials that are not fit for human use are used in the second stage of the production of biofuels. These plant resources include woody biomass, plant dry matter, as well as agricultural residues and residual plant material.
- The majority of the components that go into the production of third-generation biofuels are microorganisms and algae. Using algae fuels allows for the achievement of high yields.

There are members of the spurge family that blossom, and one of those members is the jatropha. This is a crop that is produced extensively by people all over the world for the purpose of producing ethanol. Pakistan is now in the lead in the world when it comes to the production of biofuel energy resources, according to data from 2009.

Advantages of Biofuel

- First and foremost, it promotes a healthier population.
- It helps to maintain a cleaner environment thanks to its contribution.
- All potentially hazardous gases, such as carbon monoxide (CO) and sulfur oxide (SO), are unable to escape.
- The use of biofuels rather than fossil fuels lowers the risk of cancer and respiratory problems in people since biofuels only release non-toxic ingredients. This is because biofuels are environmentally friendly.
- Because they reduce the chance of climate change, biofuels are considered to be ecologically friendly.

Disadvantages of Biofuel

- First, it interferes with the natural rhythms of life.
- Secondly, there is the expense of labor, as well as the enormous quantity of storage space that is required.
- Greater usage of water, particularly in dry locations.
- The cultivation of biomass for the production of biofuels results in an increase in the demands placed on agricultural land.

Bioenergy

The production of energy, often in the form of electricity and gas, from organic matter, also known as biomass, is referred to as bioenergy. This can include items such as plants and timber, as well as food and agricultural wastes, sewage, and other different types of waste.

Additionally included in the definition of bioenergy are fuels for transportation that are derived from organic resources. On the other hand, the only focus of this article is on its application for the generation of carbon-neutral gas and power.

How does Biomass Generate Energy?

Biomass is referred to as "feedstock" when it is exploited as a source of fuel. On the other hand, feedstocks may be made up of byproducts from industries such as agriculture, food processing, or wood manufacturing, whereas energy crops are grown specifically for the purpose of producing energy.

The burning of dry, combustible feedstocks such as wood pellets is accomplished through the use of boilers and furnaces. The water is then brought to a boil, which transforms it into steam, which is then used to drive a turbine, which generates electricity.

In order to facilitate the decomposition of moist feedstocks, such as food wastes, and the production of methane gas, sometimes referred to as biogas, tanks must be sealed off. In order to generate electricity, it is feasible to first capture the gas and then burn it. It is also possible to feed it into the gas infrastructure of the country so that it may be used for cooking and heating in residential areas.

The use of bioenergy as a solution for green electricity has a great deal of potential. It is an ideal backup for renewable energy sources that are sensitive to weather changes, such as solar and wind, because of its quick sensitivity to demand. This makes it an excellent choice for backups.

Hydrogen Economy

Hydrogen has the potential to perform a variety of activities that contribute to a hydrogen economy, which in turn decreases emissions of greenhouse gases. These functions may be performed when hydrogen is utilized in conjunction with low-carbon electricity. In regions where there are no other options that are cleaner and more cost-effective, the objective is to attain a reduction in emissions. Taking this point of view into consideration, the hydrogen economy encompasses both the production and utilization of hydrogen in ways that contribute to the reduction of climate change and the elimination of fossil fuels.

Hydrogen may be produced in a number of different formats. Gray hydrogen, which is created mostly from natural gas through a process known as steam methane reforming (SMR), constitutes the great majority of the hydrogen that is produced in the modern period. A total of 1.8% of the world's greenhouse gas emissions were attributed to this approach as of the year 2021. Low-carbon hydrogen, which may be created by electrolysis of water using renewable power or through the utilization of SMR with carbon capture and storage (blue hydrogen), accounted for less than one percent of the overall production. With regard to the yearly 100 million metric tons of hydrogen that were produced in 2021, the refining of oil was responsible for 43 percent of the total, while industry was responsible for 57 percent, mostly through the creation of methanol and ammonia for fertilizers.

The majority of people believe that in the future, gray hydrogen will be replaced by low-carbon hydrogen in the hydrogen economy, which will then contribute to the prevention of global warming. When the generation of low-carbon hydrogen will reach a sufficient level to completely remove gray hydrogen by the year 2024 is still a question that cannot be answered with certainty. Potential final applications include long-distance transportation (such as shipping, and to a lesser degree, hydrogen-powered aircraft and heavy goods vehicles), long-term energy storage, and heavy industry (e.g., high-temperature processes in conjunction with electricity, feedstock for the production of green ammonia and organic chemicals, and as an alternative to coal-derived coke for steelmaking). Other applications for hydrogen, including as heating residences and light-duty autos, are no longer anticipated for the future of the hydrogen economy. This decision was made for reasons that are both practical and ecological in nature. The utilization of hydrogen, its storage, and its transportation through pipes are all challenging endeavors. When compared to the direct use of electricity, it is inefficient and might potentially cause safety concerns owing to the fact that it has a high explosive potential. It is recommended that low-carbon hydrogen be utilized in applications that are more difficult to decarbonize in order to make the most of the limited supply of this environmentally friendly hydrogen, which is beneficial to the environment.

In 2023, there are no feasible alternatives to hydrogen in a number of the chemical reactions that require it. One of these reactions is the production of ammonia for fertilizer, which is one of the reactions that requires hydrogen. It is projected that the cost of low- and zero-carbon hydrogen will have an impact on chemical feedstocks, long-haul transportation and aircraft, as well as long-term energy storage. The prices of producing hydrogen with low or zero carbon emissions are on the rise. The future costs of energy may be influenced by a variety of factors, including carbon taxes, the volatility of energy prices, technology choices, the need for raw materials, as well as energy geography and geopolitics. The most significant reduction in the cost of producing green hydrogen is anticipated to occur over the course of time. The objective of the Hydrogen Hotshot Initiative, which is being managed by the Department of Energy of the United States of America, is to reduce the cost of environmentally friendly hydrogen to one dollar per kilogram by the year 2030.

- **Uses**

The use of hydrogen as a fuel has two distinct applications: first, it may be used in fuel cells to generate electricity, and second, it can be burned to generate heat. When hydrogen is used in fuel cells, the only emission that is created throughout the consumption process is water vapor. When hydrogen is burned, there is a possibility that they will produce hazardous nitrogen oxide emissions through heat production.

- **Industry**

In the context of reducing the effects of global warming, it is anticipated that low-carbon hydrogen, and particularly green hydrogen, will play a large role in the decarbonization of the industrial sector. One technology that helps to the decarbonization of industry is the use of electric arc furnaces for the production of steel. Another technology that contributes to this decarbonization is hydrogen fuel, which can give the high temperatures that are required for the production of chemicals, cement, glass, and steel in factories. However, its principal purpose will most likely be to offer industrial feedstock for the production of organic chemicals and ammonia in a more environmentally friendly manner. Hydrogen, for example, has the potential to serve as a low-carbon catalyst and a clean energy carrier in the steelmaking process, while also replacing coke that is sourced from coal.

It is possible that the geography of industrial operations may shift as a result of interactions between locations that have the capacity to produce hydrogen that is acceptable, logistical infrastructure, the availability of raw materials, human and technological capital, and the requirement to operate with low-carbon hydrogen in order to minimize emissions of greenhouse gases.

- **Transport**

The topic of hydrogen economy has been receiving a lot of attention as of late, and a significant portion of this attention has been focused on hydrogen vehicles, particularly airplanes. When hydrogen-powered vehicles are compared to conventional automobiles, the pollution levels in metropolitan areas are significantly reduced. Synthetic fuels and hydrogen might potentially contribute for twenty percent to thirty percent of the energy requirement for transportation in the year 2050.

In the attempt to reduce carbon emissions from transportation, it is anticipated that the principal consumers of hydrogen-derived synthetic fuels such as ammonia and methanol, as well as fuel cell technology, will be shipping, aviation, and, to a lesser extent, heavy goods trucks. Since a considerable amount of time ago, hydrogen has been utilized by fuel cell buses. Additionally, it is utilized in the propulsion of spacecraft.

The 2022 Net Zero Emissions Scenario (NZE) developed by the International Energy Agency predicts that by the year 2050, electric trains will account for 90 percent of all train traffic, which is an increase from the 45 percent that they accounted for in 2022. In contrast, hydrogen would only account for two percent of rail energy consumption in that year. There is a possibility that hydrogen might play a large role in the rail sector, particularly on lines that are difficult to electrify or that are extremely expensive. In 2050, the National Zero Emissions Initiative (NZE) predicts that large vehicles would rely on hydrogen to power around thirty percent of their energy requirements, particularly for long-distance heavy freight. At the moment, around sixty percent of this requirement is met by battery electric power.

Fuel cells, which are electrochemical in nature, are more efficient than heat engines, despite the fact that hydrogen may be used to power internal combustion engines that have been modified. Due to the higher purity hydrogen fuel needs of fuel cells, the production cost of fuel cells is higher than that of traditional internal combustion engines. This is because fuel cells require larger amounts of hydrogen fuel.

In the light road vehicle sector, which includes passenger automobiles, there were 70,200 fuel cell electric vehicles sold globally by the end of 2022. This is in contrast to the 26 million plug-in electric vehicles that were marketed. The expansion of electric cars, as well as the infrastructure and technology that support them, is causing hydrogen to lose some of its significance in the automotive industry.

- **Energy System Balancing and Storage**

The electrolysis of water results in the generation of green hydrogen, which has the potential to help smooth out variations in the production of renewable energy. The production of green hydrogen can reduce the need to cut electricity during times of high renewable power output. Additionally, during times of low renewable power output, green hydrogen can be stored and used to create power through the process of energy storage.

- **Ammonia**

With the manufacture of ammonia, which is a fuel that is both clean and renewable and can be employed either directly or indirectly, there is a simple alternative to the utilization of gaseous hydrogen as a carrier of energy. By forming a connection between hydrogen and nitrogen in the atmosphere, ammonia is produced. There are a number of problems associated with the utilization of ammonia as an energy carrier, including the fact that the production of ammonia from nitrogen and hydrogen gas has a low energy efficiency, and that PEM fuel cells can be poisoned by leftovers of undigested ammonia that are left behind after the conversion of ammonia to nitrogen gas.

- **Buildings**

There are a number of organizations that are working to reduce the amount of carbon dioxide (CO2) that buildings produce as a result of their energy consumption. These organizations are advocating for the use of hydrogen combustion boilers to heat space and water, as well as hydrogen cooking equipment. This is being done in an effort to reduce the amount of carbon dioxide that buildings produce. Consumers are not compelled to take any action at this time; the idea is that individuals who now use piped natural gas may wait until hydrogen is converted and delivered to existing natural gas networks, and then they will be able to swap out their appliances that are used for cooking and heating.

- **Bio-SNG**

The synthesis of syngas from hydrogen and carbon dioxide through the Sabatier reaction from bio-energy with carbon capture and storage (BECCS) is restricted by the quantity of sustainable bioenergy that is accessible. It is therefore probable that any bio-SNG that is produced will be set aside for use in the manufacturing of aviation biofuel, despite the fact that this is theoretically feasible in 2019.

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8

Emerging Technologies in Drug Delivery System

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Yogesh Matta**

Introduction

Many orally administered drugs have their effectiveness limited by their brief gastrointestinal transit times. Typically, single-unit dosage forms remain in the stomach for only 1 to 2 hours and move through the small intestine in about 3 hours [1]. This short duration can hinder both local therapeutic effects (i) and the ability to maintain adequate drug levels for absorption and systemic uptake (ii). For local treatments, the stomach is a key target for various medications, such as H2-antagonists [2] and antibiotics [3]. For systemic absorption, the upper small intestine is crucial, especially for drugs like levodopa [4], furosemide [5], metformin [6], and acyclovir [7], which have short elimination half-lives and are primarily absorbed there. However, the brief transit time through this segment limits absorption. To enhance local therapeutic effects or systemic uptake, the gastric and upper small intestinal transit times of drug delivery systems need to be extended.

Current delivery technologies include devices that expand rapidly once in the stomach to slow their passage through the pylorus, formulations that float on stomach fluids, and mucoadhesive systems that stick to the gastrointestinal lining.

Despite their potential, these delivery systems face significant drawbacks that can affect their effectiveness or practical use. Size-increasing formulations that expand in the stomach can lead to blockages and stomach issues [8]. Additionally, the pylorus's ability to regulate size isn't always reliable, and even large intragastric balloons used for managing obesity can end up migrating into the small intestine [9].

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Unfolding systems, while innovative, can be quite complex and might cause damage to the stomach lining, particularly if they have sharp edges [10]. Floating systems are influenced by various external factors, such as the type and amount of food consumed, eating frequency, body posture, sleep and physical activity [11]. Mucoadhesive systems also face limitations due to the constant turnover of mucus and high hydration levels in the stomach and intestines. Furthermore, there is currently no published evidence demonstrating that mucoadhesive systems can significantly extend gastrointestinal transit times in humans.

In addition to the established delivery systems developed over the past century, several promising new drug delivery technologies have emerged in recent years that could significantly impact the field. These include:

- **Mucus-Permeating Nanocarriers**: These nanocarriers can penetrate deeply into the mucus layer of the gastric and intestinal mucosa and remain there for extended periods.
- **Charge-Converting Nanocarriers**: These nanocarriers change their surface charge from negative to positive within the mucus layer near the epithelial surface, forming strong ionic bonds with the anionic mucus glycoproteins.
- **Thiolated Nanocarriers and Cyclodextrins**: These can form covalent bonds with cysteine-rich regions of mucus glycoproteins, enhancing their interaction with the mucus.

In this chapter, we will explore these emerging technologies, evaluating their potential benefits and limitations.

Delivery Technologies for Cancer Immunotherapy

The paradigm for treating cancer has changed due to the development of cancer immunotherapy, which aims to enhance anti-tumor immune responses while having fewer side effects than chemotherapy and other drugs that kill cancer cells directly [1-3]. Agents are employed in cancer immunotherapy to stimulate or activate the immune system in order to kill cancer cells by natural mechanisms, many of which are dodged as the disease progresses [1-3]. Immunotherapy is therefore acknowledged as a potentially effective treatment and even a cure for some cancers.

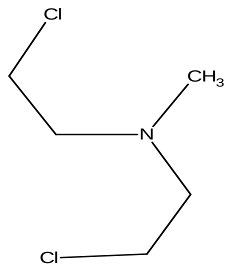
Recombinant forms of the cytokine interferon-α (IFNα) were the first commercially available immunotherapies for cancer; they were authorized by the US Food and Drug Administration (FDA) in 1986 for the treatment of hairy cell leukemia1 while IFNα2 had a short therapeutic duration, purine analogues swiftly supplanted IFNα as the first-line treatment for hairy cell leukemia, even though some patients treated in these early clinical trials had partial remission. Recombinant interleukin-2 (IL-2) was then studied as an immunotherapy for cancer and licensed by the FDA in 1992 for metastatic renal cancer and in 1998 for metastatic melanoma.

When IL-2 therapy was first introduced, it was welcomed since some patients showed complete, long-lasting responses to it [4]. However, due to IL-2's short half-life, substantial doses were necessary, which resulted in a number of major side effects, including vascular leak syndrome and cytokine release syndrome [5,7]. Even if the early clinical investigations of these treatments showed promise, the failure of numerous vaccine clinical studies played a major role in the 2000s cancer immunotherapy field's stagnation.

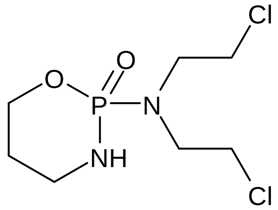
The first therapeutic cancer vaccine, **sipuleucel-T** (an autologous dendritic cell therapy), was approved for prostate cancer in 2010 after nearly ten years of largely unsuccessful vaccine trials. However, production complications and other issues hindered its clinical translation [9,10]. A few years later, in 2011, the ground-breaking checkpoint inhibitor ipilimumab—a monoclonal antibody (mAb) that targets cytotoxic T lymphocyte antigen 4 (CTLA4)—was authorized for the treatment of metastatic melanomas. In recent years, new immunotherapies have been developed and licensed for clinical use. These include checkpoint inhibitors, monoclonal antibodies (mAbs) that target programmed cell death 1 (PD-1) or its ligand, PD-1 ligand 1 (PD-L1) [12], and the first chimeric antigen receptor (CAR) T cell therapies [13–16]. Science named ipilimumab and CAR T cell treatments the 2013 breakthrough of the year, highlighting their revolutionary role in cancer immunotherapy.

The clinical application of immunotherapies still confronts a number of safety and efficacy-related obstacles despite these significant advancements. It is challenging to predict patient responses when it comes to efficacy because only some patient subsets respond to immunotherapies [18]. Additionally, there is a lot of interest in creating immunotherapies tailored to individual patients based on the expression of biomarkers on cancer cells and in assessing combination treatment plans to increase response rates [19–21].

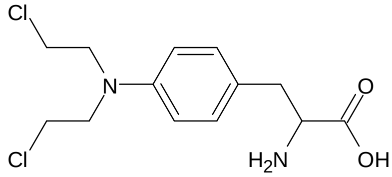
The various drugs or agents are used in the treatment of cancer viz. Mechlorethamine, Cyclophosphamide, Melphalan, Chlorambucil, Thiotepa, Mercaptopurine, Thioguanine, Fluorouracil, Methotrexate, Aminopterin, Cisplatin, Mitotane etc.



Mechlorethamine



Cyclophosphamide



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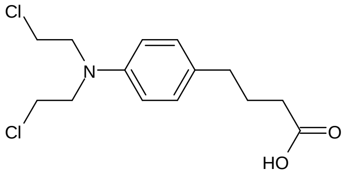

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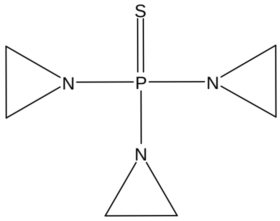

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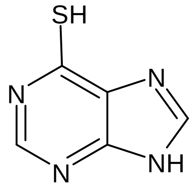
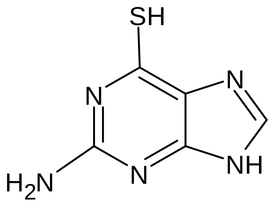
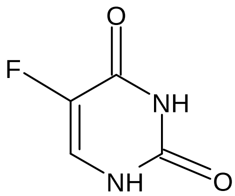


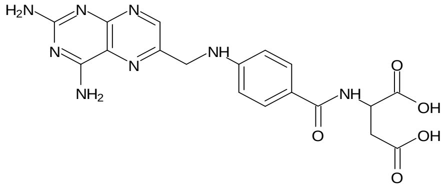
Mercaptopurine



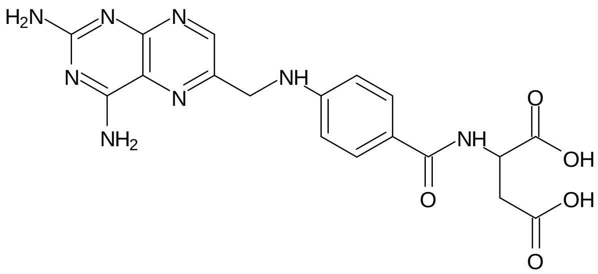
Thioguanine



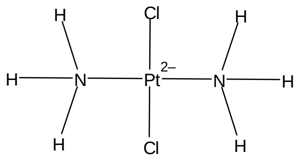
Fluorouracil



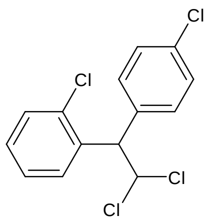
Methotrexate



Aminopterin



Cisplatin



Mitotane

- **Classes of Cancer Immunotherapy**

The delivery methods for immunotherapies that fall under one or more of the following five categories are covered in this article: cancer vaccines, agonistic antibodies against co-stimulatory receptors, checkpoint inhibitors, lymphocyte-promoting cytokines, engineered T cells such as CAR T and TCR T cells, and TCR T cells.

- **Checkpoint Inhibitors**

To date, checkpoint inhibitors have been the most extensively studied class of immunotherapy. The two most popular checkpoint inhibition techniques are CTLA4 inhibition and PD-1/PD-L1 blocking. A detailed overview of other checkpoint inhibitors at previous stages of clinical development can be found elsewhere [41-43].

Immunological checkpoints function physiologically to preserve proper immunological responses and defend healthy tissues from immune assault [41]. T cells express PD-1 when they become activated, such as in response to inflammation, and this helps them identify aberrant and malignant cells [44,45]. Tumor cells express PD-L1, which binds to PD-1 on T cells to inactivate those cells in order to avoid being recognized and eliminated by T cells [44,46]. T cell-mediated cancer cell death is therefore made possible by inhibiting this connection with mAbs that target either PD-1 or PD-L1. CTLA4, a co-inhibitory molecule, is another immunological checkpoint that controls the degree of T cell activation. CTLA4's ligands, CD80 and CD86, interact with one another to suppress T cell activation, which accelerates the growth of tumors [42]. T cells are able to recognize and eliminate tumor cells by preventing CTLA4 from interacting with these ligands. It is crucial to remember, nonetheless, that there are still questions about the exact cellular mechanisms behind CTLA4 inhibition, and that the properties of the various CTLA4-targeted antibodies vary47. Some anti-CTLA4 antibodies, for instance, have been shown to both reduce the number of regulatory T cells and impair checkpoint performance [48,49].

- **Cytokines**

After recombinant IFNα therapies were approved in 1986, cytokines were the first type of immunotherapy to be introduced into the clinic. In contrast to checkpoint blocking techniques, this approach uses administered cytokines to directly stimulate immune cell development and activation. Interleukins, granulocyte–macrophage colony-stimulating factor (GM-CSF), and interferons are the three primary cytokine types that have been investigated for immunotherapy4. Immune cells generally create interferons in response to microbial infections. These interferons cause many immune cells, including as macrophages, natural killer (NK) cells, lymphocytes, and dendritic cells, to mature and trigger an immunological response [58–61]. Inhibiting angiogenesis in the extracellular tumour area can also be achieved by immune cell activation with interferons [4,59,62]. Interleukins promote CD4+ and CD8+ T cell proliferation and activation [63–66]. Lastly, GM-CSF enhances immune responses by supporting dendritic cell development, which results in the expression of tumor-specific antigens [67], and encouraging T cell homeostasis, which enhances T cell survival. Although GM-CSF may be more pro-inflammatory than G-CSF [67–69], both granulocyte colony-stimulating factor (G-CSF) and GM-CSF have been utilized to enhance and speed granulocyte recovery following chemotherapy.

Cancer Vaccines

Tumor cell lysate, dendritic cells, nucleic acids (such mRNA), or neo-antigens105 are examples of cancer vaccine types. We will discuss the last three here for the sake of brevity, and readers interested in learning more about vaccines generated from cancer cell lysate should consult published review papers [106,107].

The class of cell-based cancer vaccines that is most often researched is dendritic cell vaccines [55]. Vaccines utilizing dendritic cells are created by culturing dendritic cells from patients that have been genetically modified to produce antigens linked to tumors, thereby directly stimulating T lymphocytes to target cancer cells [55]. As previously mentioned, in 2010 the dendritic cell vaccine sipuleucel-T was licensed for the treatment of prostate cancer due to its ability to extend overall survival [9,108]. Despite having excellent safety ratings, other vaccines based on dendritic cells have not proven effective in clinical studies. Enhancing distribution to the appropriate lymph nodes [55,109,110] and identifying specific subsets of dendritic cells that express high quantities of targeted antigens55 are expected to increase efficacy.

Nucleic acid treatments, which depend on the intracellular delivery of exogenous nucleic acids into target cells, have emerged as viable substitutes for conventional vaccines. Examples of these vaccines are DNA- and RNA-based vaccines. In these technologies, APCs absorb DNA or mRNA, which they then translate to cause the production of antigens. T lymphocytes are exposed to the targeted antigens in order to activate them against tumor cells that express the desired antigen [111]. Numerous clinical trials have tested DNA vaccines, but due to immunogenicity and nuclear delivery obstacles, they frequently end in failure [104-112].

On the other hand, mRNA-based cancer vaccines have been created to force APCs to express antigens linked to immunological recognition directly [111]. Since mRNA is a molecule that occurs naturally, it is simple to generate and can have its half-life extended through modification. In addition to not integrating into the genome like many DNA vaccines do, mRNA is non-infectious [111,115]. However, mRNA cannot readily be internalized by cells and is rapidly broken down by nucleases; therefore, transfection agents or delivery platforms are needed to facilitate intracellular delivery [111,116]. Therefore, delivery strategies that enhance intracellular (for mRNA) or intranuclear (for DNA) delivery can be highly advantageous for nucleic acid vaccines.

Need for Novel Delivery Technologies

Each of the five immunotherapy classes covered here has delivery issues, some of which are common to all of them and some of which are unique to their own class. The administration of agonistic antibodies, cytokines, and checkpoint inhibitors is fraught with comparable difficulties. These treatments' ability to connect with the targeted protein determines how well they work. The fact that they significantly increase autoimmunity and cause side effects that restrict the amount that can be provided is a significant restriction on their use [26]. Therefore, enabling targeted and regulated release to make the therapies primarily active in the intended cell types is a fundamental goal in the development of delivery methods for these therapies, which should minimize off-target effects.

All of the immunotherapy classes covered here [121] face challenges due to the microenvironment found in many solid tumors. For instance, the immunological milieu of solid tumors can be classified as "cold" (low immunogenicity) or "hot" (high immunogenicity), depending on the degree of cytotoxic lymphocyte infiltration within the tumor space [121]. This significant variation in the micro environmental makeup implies that, in comparison to tumors with low immunogenicity, those with high immunogenicity demonstrate more robust responses to checkpoint inhibitors [121]. Therefore, delivery strategies can be used to influence the immunogenicity of cold tumors. Delivery platforms can also be utilized to deliver combinations of medicines that would otherwise be too toxic to give to patients, as they can limit drug exposure to specific tissues [25,122], so reducing the systemic toxicity of immunotherapies.

Liposomal nanoparticles were complexed with a PD-L1 trap plasmid (to block PD-L1 signalling) and cationic protamines to generate lipid–protamine–DNA (LPD) nanoparticles, which are targeted to tumor tissue using amino–ethyl anisamide ligands [122]. This is a beautiful illustration of the combination effect in action. LPD nanoparticles and the chemotherapeutic medication oxaliplatin, which has been demonstrated to activate dendritic cells and stimulate immunological activity in tumors in addition to its DNA-damaging actions in tumor cells, were delivered intravenously into mice carrying orthotopic colorectal tumors [122]. Oxaliplatin may therefore turn immunologically cold tumors into hot tumors that are more responsive to LPD therapy. When compared to animals given with PD-L1 antibodies and oxaliplatin without a nanoparticle carrier, the tumour-targeted LPD nanoparticles and oxaliplatin demonstrated decreased toxicity and combined effects to limit tumor growth [122]. This illustrates how combination treatment options with nanoparticles may be able to increase the immunogenicity of tumors with poor immunogenicity.

Nanomedicines can be engineered to react to the tumor microenvironment and enhance penetration at those areas, in addition to facilitating combination therapy strategies. An intriguing illustration of this was observed when 10 nm quantum dots were coated on 100 nm gelatin nanoparticles, which were then exposed to matrix metalloproteinase (MMPs), which are frequently found in tumor microenvironments. The present investigation used a dorsal skin-fold window chamber model to implant nanoparticles into fibro sarcomas. The tumor tissue was significantly more perforated by the quantum dots encapsulated on the nanoparticles than by the nonreactive quantum dots by themselves [123]. Therefore, this novel design could be used to transport medicines through solid tumors with both high and low immunogenicity—the latter of which would not normally respond to immunotherapy—by substituting the quantum dots with therapeutic-loaded nanoparticles.

Transdermal Delivery

Despite the approval of systemically administered checkpoint inhibitors targeting CTLA4 or PD-1 for the treatment of melanoma, a significant fraction of patients do not respond to treatment (for instance, the objective response rate in metastatic melanoma is less than 40% when using the anti-PD-1 mAb nivolumab) [203]. In order to minimize the necessary dose, minimally invasive transdermal delivery devices have been developed to allow for the regulated, sustained release of anti-PD-1 mAbs at the disease site [38,143,204]. These delivery methods include a degradable microneedle patch205, which can deliver immunotherapeutics to the immune cell-rich epidermis of the skin painlessly [38,143]. Usually made of a biodegradable polymer like hyaluronic acid, microneedles are packed with anti-PD-1-containing pH-sensitive nanoparticles (REF.143). pH-sensitive nanoparticles release anti-PD-1 to locally engage the immune system against cancer cells in the moderately acidic tumour microenvironment. Compared to non-pH-responsive microneedles or intratumoural injection of free anti-PD-1 antibodies, a single administration of the microneedle-based patch induced a robust immune response in a mouse model of melanoma, achieving 40% survival after 40 days, while other treatment groups died after 30 days143.

Conclusion & Future Directions

Before immunotherapeutics may be used with a wide variety of patients, there are still significant obstacles to overcome; many of these could be resolved by advancements in drug delivery technology. While immunotherapy has been widely researched and used to melanoma and hematological cancers, solid tumors have not been successfully targeted by currently accessible immunotherapies. A deeper comprehension of immune cell trafficking into solid tissues may facilitate the delivery of immune cells to solid tumors. As an illustration, it has been demonstrated that CAR T cells can cross the blood–brain barrier [128,231]. This is thought to be a result of people with specific disorders having greater blood-brain barrier permeability, while the exact mechanism underlying this is yet being studied231. Advances in T cell engineering to express CARs, including multiplexed genome editing using CRISPR-Cas [9,232,233], may enhance our basic knowledge of T cell transport to target organs.

Because of the potentially immunosuppressive tumor microenvironment, high interstitial fluid pressure, compressed vasculature, and dense fibrotic tissue that surrounds solid tumors and prevents T cell entry, targeting immune cells to solid tumors by cell transfer or immunization is challenging. More efficient immunotherapies may result from future strategies that target the tumor microenvironment in addition to the immune system. For instance, the mechanism by which angiotensin II inhibitors modify the tumor microenvironment in patients with nonmetastatic pancreatic cancer was assessed [234].

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9

Climate Change Mitigation and Adaptation

Dr. Sushma Loth*

Introduction

Carbon Capture and Storage

Through the process of carbon capture and storage (CCS), a stream of carbon dioxide (CO2) that is relatively pure is extracted, cleaned, and transported to a facility that is designed for long-term storage. This process is carried out from industrial sources. After being collected from a large point source, such as a chemical factory, coal power station, cement kiln, or bioenergy plant, carbon capture and storage (CCS) typically entails storing carbon dioxide (CO2) in a geological formation that is suitable for the purpose.

However, there are many who say that carbon capture and storage (CCS) projects have actually raised emissions rather than lowered them. This is despite the fact that CCS has been considered as a solution to limit our influence on the environment via the reduction of emissions of greenhouse gases. In order to accomplish the objectives of the Paris Agreement and reduce emissions from the power sector, one of the options available is to retrofit existing power plants with carbon capture and storage systems. However, the majority of carbon capture and storage plants are designed for the processing of natural gas, and as of the year 2022, CCS is only capable of capturing one thousandth of the total CO2 emissions in the globe. There is a great majority of existing systems that are not meeting the threshold of 90% capture efficiency, despite the fact that this is the norm for carbon capture and storage programs.

When carbon dioxide is captured, it is frequently deposited in mineral carbonates or in geological formations that are deep underground. Long-term

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projections on the safety of underground or subsurface storage are difficult to establish because of the level of difficulty involved. Even now, there is still a chance that some carbon dioxide will escape into the sky. An investigation that was carried out in 2018 came to the conclusion that the likelihood of a significant leakage was quite low. Beginning in the year 2022, about 73% of the CO2 that is collected annually will be accounted for by the enhanced oil recovery (EOR) technique. This technique includes injecting carbon monoxide into oil reservoirs that have been partially depleted in order to retrieve additional oil before it is left underground. Other names for EOR include carbon capture, usage, and storage (CCS), which is a method that not only stores carbon dioxide but also makes use of it.

At this point in time, CCS is still considered to be a somewhat expensive operation. When the price of carbon is high, as it is across the majority of Europe, carbon capture becomes a more realistic alternative to consider. Those who are opposed to carbon capture and storage (CCS) contend that it is an inefficient method of tackling the climate crisis. According to them, the fossil fuel industry had a significant role in the development of the technology as well as in encouraging the passage of regulations that give priority to carbon capture and storage. The concept of carbon capture and storage is considered by some individuals to be nothing more than a greenwashing scheme to cover up the detrimental effects that the fossil fuel industry has on society and the environment. In terms of public support, regions that have a history of experiencing negative consequences as a result of industrial activity are less likely to adopt carbon capture and storage (CCS). In addition, communities may be opposed to the development of carbon capture and storage (CCS) if they believe they are being misinformed or excluded from the decision-making processes about the project.

On a worldwide basis, there are a number of policies and legislation that either promote or even mandate the utilization of carbon capture and storage (CCS). The Infrastructure Investment and Jobs Act of 2021 provide funding for some carbon capture and storage (CCS) projects in the United States. Additionally, the Inflation Reduction Act of 2022 would revise tax credit laws in order to encourage the utilization of CCS. Initiatives to support carbon capture and storage (CCS) technology is being developed not just by the United Kingdom but also by Canada, Denmark, and China.

Purpose

- **Early uses**

The natural gas industry has been successfully using carbon capture technologies for a considerable amount of time. Before natural gas can be processed into a product that can be sold, the CO2 gas that is present in the raw natural gas must be eliminated. Natural gas development projects are now more financially viable as a result of the sale of carbon dioxide (CO2) to oil firms for the purpose of enhanced oil recovery (EOR). In 1972, the Terrell Natural Gas Processing Plant, located in Terrell, Texas, United States, proved to be the pioneer in the removal of carbon dioxide for this motive. Emissions of carbon dioxide (CO2) created by humans can be reduced by the use of a relatively recent method known as carbon capture and storage (CCS). The Sleipner Carbon Capture and Storage (CCS) project was launched in 1996, while the Weyburn-Midale Carbon Dioxide Project was launched in 2000. Both of these projects were international demonstrations of large-scale collection, utilization, and storage of anthropogenic carbon dioxide emissions.

- **Role in Climate Change Mitigation**

CCS, which stands for carbon capture and storage, is predicated on the concept that it is possible to continue utilizing fossil fuels while simultaneously reducing our CO2 emissions and, as a result, mitigating the effects of climate change.

In the present day, carbon capture and storage, often known as CCS, is being utilized to assist in mitigating the effects of climate change. The retrofitting of existing power stations with carbon capture and storage technology is one technique that may be utilized to reduce emissions from the power sector in accordance with the objectives set out in the Paris Agreement. Despite the fact that the global deployment rates of carbon capture and storage (CCS) are currently far lower than the mitigation scenarios presented in the IPCC Sixth Assessment Report, modeling studies have demonstrated that CCS is not risk-free when utilized in excess. In the year 2021, the amount of CO2 that could be captured annually was a modest 45 million tons. When compared to initiatives that do not involve carbon capture and storage (CCS), the deployment of default technology assumptions would result in a cost that is 29-297% more over the course of a century in a scenario with 430-480 ppm CO2/yr.

In 2018, shared socioeconomic pathways, also known as SSPs, were developed in order to incorporate a socioeconomic aspect into the integrated work that was initiated by RCPs models. The objective of this work was to maintain a global warming that was below 2.0 degrees Celsius. The utilization of unconstrained fossil fuels or technologies that do not involve carbon capture and storage is not permitted in any of the scenarios that involve SSPs. We will need to employ bioenergy in conjunction with carbon capture and storage, sometimes known as BECCS, if we wish to limit the increase in global temperature below 1.5 degrees Celsius. We will still be required to remove between 150 and 12,000 GtCO2 from the atmosphere, even with BECCS.

According to the findings of a research conducted in 2019, carbon capture and storage (CCS) facilities were shown to be less effective than renewable power sources. An analysis of the electrical energy returned on energy invested (EROEI) ratios for two production systems was carried out after the operational and infrastructural energy expenditures were taken into consideration. When it comes to the generation of electricity from renewable sources like solar and wind, it is necessary to have sufficient energy storage as well as the capability to be dispatched. For this reason, it would be preferable to rapidly grow scalable renewable power and storage rather than relying on fossil fuels that are capable of carbon capture and storage.

- **CO_2 Capture**

Point sources, which include large energy facilities that are dependent on fossil fuels, businesses that produce a significant amount of carbon dioxide (such as cement and steel), businesses that process natural gas, plants that produce synthetic fuels, and plants that produce hydrogen using fossil fuels, are the most cost-effective places to capture carbon dioxide. Although it is theoretically possible to extract carbon dioxide from air, as compared to combustion sources, the concentration of carbon dioxide in air is significantly lower, which makes the process technically more complicated and, as a result, more expensive. It is not possible for projects that involve carbon capture to achieve an efficiency of net storage that is higher than 6–56%. A little less than two thirds of the cost of capture is accounted for by CCS. In light of the fact that carbon capture, storage, and transportation are already well-established processes, optimizing capture would significantly improve the practicability of carbon capture and storage.

It is possible for contaminants such as water and sulfurs to have a major impact on the phase behavior of CO2 streams. This, in turn, can make the corrosion that can occur in pipelines and wells even more severe. A scrubbing separation operation is the initial stage in the process of cleaning the flue gas when CO2 impurities are present. This procedure is especially required when air capture is being utilized.

A number of different separation methods, including gas phase separation, liquid absorption, solid adsorption, and hybrid processes such adsorption/membrane systems, are now being researched. These are only some of the numerous strategies that are being investigated. Oxy-combustion, post-combustion capture, and pre-combustion capture are the three approaches that may be utilized to accomplish this technique of capturing:

  - It is possible that power plants that rely on fossil fuels might use an approach known as post combustion capture, which includes the removal of carbon dioxide (CO2) shortly after the combustion process has been completed. Flue gas contains carbon dioxide, which is collected by power plants and other point sources of CO2. The technique is widely understood and has other applications in the industrial sector, despite the fact that it has not yet been implemented on a commercial scale. Because it provides the greatest opportunity for effectively retrofitting fossil fuel power plants with carbon capture and storage technology, post-combustion capture is a topic that researchers are particularly interested in.

- Pre-combustion methods are utilized extensively in a variety of industries, including fertilizer, chemicals, gaseous fuel (H_2, CH_4), and power generating processes. Here, the fossil fuel passes through a process of partial oxidation, similar to what happens in a gasifier, for instance. As a result of the reaction with the extra steam (H_2O), the carbon monoxide (CO) that was produced from the syngas (CO and H_2) is transformed into carbon dioxide (CO_2) and hydrogen (H_2). It is possible to capture the CO_2 that is produced by using an exhaust stream that is quite clean. If you first remove the carbon dioxide gas from the hydrogen before burning it, you will be able to use the hydrogen as fuel. In contrast to post-combustion capture, there are a number of advantages and disadvantages that should be taken into consideration. The flue gas is filtered in order to remove carbon dioxide (CO_2) before it expands to the pressure of the atmosphere at the end of the burning process. Nearly all industrial CO_2 capture technologies incorporate the collection of CO_2 before expansion, which means that it is obtained from compressed gas. This is done at the same scale that is required for power plants.
- Oxy-fuel combustion is a type of combustion that employs pure oxygen as the medium for burning rather than air. The temperatures of the flames that are produced thereafter are maintained at levels that are characteristic of traditional combustion by the process of recirculating and injecting flue gas that has been cooled into the combustion chamber. A significant portion of the flue gas is made up of carbon dioxide and water vapor that has been condensed. The ultimate result is a stream of carbon dioxide that is almost entirely clean. Power plant operations that are based on oxyfuel combustion are sometimes referred to as "zero emission" cycles. This is due to the fact that the CO_2 that is stored is not a proportion removed from the flue gas stream (as is the case in pre- and post-combustion capture), but rather the flue gas stream itself. There is always going to be some carbon dioxide in the condensed water. Therefore, in order to be eligible for the "zero emission" claim, water must be treated or disposed of in an appropriate manner.

The absorption approach, which is sometimes referred to as carbon cleaning using amines, is the most prevalent method of capture. To the best of our knowledge, it appears that no other method of carbon capture has yet been utilized in any industrial setting. Multiple carbon capture techniques have been suggested, including chemical looping combustion, membrane gas separation, calcium looping, and metal-organic frameworks. These are only some of the systems that have been presented:

- Immediately following the acquisition of the CO2 that has been collected, it is customary to compress it into a supercritical fluid. The carbon dioxide is compressed so that it may be transported more easily. At the moment when compression is applied, the capture point is located. This technique requires a distinct source of energy in order to be carried out. The load of the parasite is enhanced during compression, just as it is during capture. In order to accomplish the energy-intensive process of CO2 compression, it is necessary to have a cooling process that is powered by power and complex compressors that have many stages.

- **CO_2 Transport**

Pipes are already being used to transport a certain amount of carbon dioxide under enormous pressure. Utilizing the United States of America as an example, there were more than 5,800 kilometers of CO2 pipelines that were operational in the year 2008. In addition, Norway had a network that stretched for 160 kilometers and carried carbon dioxide to oil producing areas. This carbon dioxide is then injected into older fields in order to boost oil output.

In 2021, two companies, Navigator CO2 Ventures and Summit Carbon Solutions, were in the process of developing pipelines that would connect ethanol plants to areas in the Midwest where porous rock is pumped with liquid carbon dioxide. These pipes would be used to transport carbon dioxide. As far as Illinois is concerned, the pipes would extend from North Dakota. The Navigator Heartland Greenway pipeline project was scrapped as a result of a significant amount of protest from stakeholders in the surrounding community. In a similar vein, the Summit Carbon pipeline has been confronted with significant difficulties since the year 2023, and it is now estimating a COD for the year 2026.

In transmission pipes, there is the possibility of damage or leaking. In the event that it is destroyed, a 19-inch pipeline section that is 8 kilometers long has the potential to release 1,300 tons in 3 to 4 minutes. Operators have not been compelled to retrofit older pipes with remotely controlled valves that limit the release quantity to one section of the pipe due to the nonapplication clause at 49 U.S.C. § 60104(b), which forbids the Pipeline and Hazardous Materials Safety Administration (PHMSA) from imposing regulations on existing facilities.

Forty-five individuals were left unconscious and others were rushed to the hospital as a result of an explosion that occurred near Satartia, Mississippi, in the year 2020. Some of those affected by the explosion will experience long-term health repercussions.

It is the responsibility of the United States Pipeline and Hazardous Materials Safety Administration, which is notoriously understaffed and underfunded, to ensure that pipelines are safe to use.

- **CO_2 Sequestration (Storage)**

There are a few different approaches that have been suggested for long-term archiving. CO2 may be stored in both gaseous and solid forms. The former involves the interaction of CO2 with metal oxides to build stable carbonates, while the latter occurs in deep geological formations such as salt formations and depleted gas fields. Both of these modes of CO2 storage are conceivable. Before making a decision about whether or not to proceed with CO2 storage, it is required to conduct a comprehensive study of the storage capacity, containment efficiency, and injectivity of a geological formation. When carbon dioxide is pumped into underground rock formations, it is often in a supercritical condition. This process is known as geo-sequestration. Basalt formations that are filled with water, oil and gas deposits, coal seams that cannot be mined, and salt formations are all examples of possible replacements. At the molecular level, it has been established that carbon dioxide may affect the mechanical properties of the material that has been injected for injection. It is not possible for carbon dioxide to reach the surface due to the presence of physical and geochemical trapping mechanisms, such as caprock that is extremely impermeable.

Due to the fact that carbon dioxide molecules adhere to the surface of the coal, even seams of coal that cannot be mined possess potential for utilization. A determination of the technical feasibility is made based on the permeability of the coal bed. Through a process known as enhanced coal bed methane recovery, it is feasible to accomplish the task of collecting the methane that coal releases during the process of absorption. Methane profits have the potential to pay for a portion of the cost; nevertheless, the combustion of this methane results in the production of an additional stream of carbon dioxide that has to be stored.

The mineralized brines that can be found in salt deposits have not yet shown to be beneficial to human beings. To a limited extent, saltwater aquifers have been employed for the purpose of storing chemical waste sometimes. The most important characteristics of saltwater aquifers are their copious amounts of water and their tremendous potential for storage. The most significant disadvantage of saltwater aquifers is the paucity of knowledge that exists about them. It is possible that geophysical inquiry may be reduced in order to keep storage costs within acceptable ranges, which will result in increased uncertainty regarding the structure of the aquifer. In contrast to coal beds and oil fields, there is no byproduct that can compensate for the significant amount of money that is spent for storage. An immobilization of the gas underneath can be accomplished by the use of many trapping strategies, such as structural, residual, solubility, and mineral trapping. This will reduce the possibility of CO_2 escaping from the system.

- **Enhanced Oil Recovery**

The utilization of carbon dioxide (CO_2) to enhance oil recovery in regions that have been largely depleted has been going on for decades. Burning the gas or oil is stated to result in the production of extra emissions into the atmosphere.

Leakage Risks during Storage

- **Long-term Retention**

According to the Intergovernmental Panel on Climate Change (IPCC), the risks of leakage for sites that are adequately managed are comparable to those of hydrocarbon operations that are already in place. One of the suggestions is to restrict the quantity of leakage that can take place. On the other hand, this conclusion is open to question because there is no background information provided. Even while some leakage is unavoidable, suitable storage places have the capacity to keep more than 99% of carbon dioxide for more than a thousand years. In light of this, it is possible that the CO_2 will be preserved for millions of years. In order to reduce the possibility of leaks occurring, a variety of different approaches have been investigated and proposed. One other tactic includes making advantage of sandstone strata that contain a significant amount of clay.

There is no risk of leakage associated with the storage of minerals, according to the current view.

One of the first initiatives of this sort to be carried out on an industrial scale is the Sleipner gas field, which is located in Norway. An environmental research conducted after geosequestration had been in operation for ten years came to the conclusion that it was the most definite method for permanent geological storage:

According to the geological evidence that is now accessible, there were no important tectonic events that occurred after the Utsira formation, which is a salt reservoir, was deposited. The conclusion that can be drawn from this is that the geological context is not only tectonically stable but also suitable for the storage of carbon dioxide. Through the use of solubility trapping, geological resources may be stored in a manner that is both secure and long-lasting.

After almost a decade of operation, a study revealed that carbon dioxide was gradually spreading throughout the formation, as stated by the national Norwegian oil giant StatoilHydro, which was subsequently renamed Equinor. The conclusions of the research were made public in March of 2009.

The identification of gas leaks and the direct quantification of these leaks via the use of eddy covariance flux measurements are both made possible by the monitoring of ambient water levels.

- **Sudden Leakage Hazards**

It is possible that non-return valves will be put on the injection pipe at the storage location in order to prevent an uncontrolled release from the reservoir in the event that the pipeline upstream sustains damage.

Large-scale emissions of carbon dioxide bring about an increase in the risk of asphyxiation. In the Menzengraben mining accident that occurred in 1953, for instance, a person who was 300 meters away died of asphyxiation when hundreds of tons of material were released into the environment. When an industrial fire suppression system with a capacity of fifty tons of carbon monoxide stopped working in a large warehouse, fourteen people passed out on the public road that was adjacent to the building.

Climate-Resilient Infrastructure

A item is said to be "climate resilient" if it is able to withstand natural catastrophes that are made worse by climate change and recover quickly from their effects. It will be necessary to rethink and rebuild a significant portion of our infrastructure in order to make it more resistant to the effects of climate change, which either makes natural disasters such as hurricanes, floods, heat waves, and wildfires considerably more severe or causes them to spread to new locations.

What does resilience look like?

To be resilient to the effects of climate change, one must first adequately prepare for it, then adapt to it, and then recover from it.

In order to be adequately prepared, it is essential to construct buildings that are capable of withstanding powerful shocks and blowing winds. Some buildings might become more climate resilient by making straightforward improvements such as installing storm shutters or attaching shelving. These are only two examples of such adaptations. A number of them will require significant modifications, such as elevating the structure off the ground, strengthening structural components, or utilizing materials that are resistant to fire. Additionally, in order to protect some cities from storms that are more powerful, it will be essential to construct additional structures, such as levees and seawalls made of concrete.

Providing the locals with information about potential threats is another component of being prepared. This allows them to seek cover or evacuate the area in the case of an emergency. There are a few different ways that notifications may be delivered, including evacuation routes, SMS alerts, and maps of possible hazard zones. It is imperative that these topics be communicated in several languages in a country as diversified as the United States of America.

The notion of adaptation emphasizes the demand for adaptable solutions to developing danger risks, which are particularly common in a warming planet. To offer an example, climatic projections demand constant modifications to zoning laws and construction rules. Zoning regulations define where buildings may be situated, and building standards dictate how buildings must be erected. In order to ensure that older houses are in compliance with the regulations, retrofitting is also required. Finally, individuals of the community need to get themselves ready for the recovery process by creating plans and putting money away. A complete and quick recovery is required in order for the therapy to be effective.

The implication of this is that homeowners need to be able to quickly assess the damage, report it to their insurance carriers, and then initiate repairs. In addition, every level of government ought to be prepared to lessen the difficulty of this endeavor. An illustration of this would be the fact that if roads are not cleansed of debris after a storm, it may be more difficult to rebuild and distribute aid after the catastrophe. In order to facilitate the healing process, it is essential that normal business and public service activities be resumed after a catastrophe has occurred. After Hurricane Katrina, the New Orleans areas that reopened their schools the earliest saw the shortest recovery timeframes, according to the findings of researchers from the Department of Urban Studies and Planning at the Massachusetts Institute of Technology.1.

- **Achieving Safety and Affordability**

Infrastructure that is climate-resilient is a win-win situation since it saves lives and money. According to the findings of a research that was carried out by the MIT Concrete Sustainability Hub, investments in climate-resilient architecture can prevent sufficient damage to repay their costs in as little as two years in areas that are prone to dangers.2. For every dollar that you invest in resilience, you may stand to save up to eleven dollars in repair costs, according to the findings of other study.3)

An important duty that falls on the shoulders of governments is the creation of infrastructure that is resilient enough to survive the consequences of climate change. With that being said, they do own a number of resources that other actors might potentially utilize in order to invest in climate resilience initiatives. First and foremost, they have to prioritize the implementation of improved construction processes and the restriction of constructing in high-risk zones. Following a natural disaster, communities often experience some of the most devastating repercussions, including the displacement of residents, the postponement of repairs, and the closure of businesses. These policies have the potential to assist ease some of the challenges that communities face. Additionally, they reduce the burden that is placed on communities as a result of huge public works projects such as levees, which should only be done as a secondary strategy to prevent disasters rather than as a main measure.

Through government programs that provide tax incentives, insurance, subsidies, and buy-outs, individuals can get assistance in their preparations for climate change or in abandoning the constructions that are now the most vulnerable to the effects of climate change. In order for the general people to take part in these projects, it is essential to educate them about the benefits of climate resilience and the programs themselves. Within the United States of America, there are a number of non-governmental organizations (NGOs) that promote for resilient construction methods and educate the general public on how to make educated decisions regarding house and business renovation projects, as well as how to acquire funding for these projects.

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10

Impact of Plastic on Environmental and Public Health

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Introduction

The emergence of new technology and the unavoidable population growth cause certain shifts in societal consumption patterns. Along with the expansion of welfare, these developments led to the development of new and unique materials, including plastics, which are now an essential part of our everyday life. These materials are popular because they have a number of desired qualities, including i) high resistance combined with light weight; ii) easy facilities for manufacturing; iii) cheap prices; iv) reusability; and v) preservation of natural resources as reported by Panda, A. et al., (2010).

According to Rochman (2018), it has been clear over the last ten years that plastic waste is a pollution that is present everywhere in the world. Around the world, plastic may be found in freshwater, marine, and terrestrial environments.

In the study of Zbyszewski and Corcoran (2011), it was reported that shipping spills or inappropriate disposal are the main causes of the buildup of plastics in our surroundings. Plastics are strong and lightweight, so they may travel great distances and wind up on land, along coastlines, or drifting in the open ocean.

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Fig. 1: Plastic Pollution

Source: https://shorturl.at/YHagH

Today's world relies heavily on plastics for a variety of purposes, such as building, technology, healthcare, and athletic wear. Plastics have many advantageous qualities that are hard to achieve with other materials. For instance, depending on the kind of polymer, plastics may be heated, sterilized, and manipulated without losing their structural integrity. Additionally, they can be used in place of other non-sustainable animal-based items including fur, tortoise shell, and ivory. In addition to being lighter than other materials like glass, plastics emit fewer carbon emissions during transportation, as examined by Miller (2020).

However, because they are inexpensive and disposable, they are frequently used and thrown away needlessly. The conflicting benefits and drawbacks of plastics have never been more evident than during the COVID-19 pandemic when plastic-based personal protective equipment (PPE) and packaging have helped stop the virus's spread while also contributing to a detectable rise in the number of plastic debris in the environment, as reported by de Sousa (2020).

Unsustainable plastic production and mismanagement have led to pervasive micro(nano) plastic(microplastics (<5 mm) or nanoplastics (<1 μm or 1000 nm) pollution) harming ecosystems and contributing to climate change. Existing mitigation efforts are inadequate. The need for holistic strategies to curb pollution, critiques current approaches, and suggests improvements to achieve global sustainability targets for plastics as reported by Walker, T. R., & Fequet, L. (2023).

Plastic pollution is a highly visible global environmental challenge, requiring more than science and technology to address effectively. Environmental education offers a low-cost, impactful solution by fostering prevention through school programs, public awareness, and sustainable consumption practices. This approach provides a feasible, effective, and lasting pathway to combating plastic pollution as investigated by Liu, J. et al. (2023).

Harmful Compound in Plastic

Polyvinyl chloride (PVC) and polyethylene terephthalate (PET) are the most commonly consumed plastics worldwide. The most common substance used to bottle water is polyethylene terephthalate (PET), which is produced when terephthalic acid and ethylene glycol combine. In addition to the key characteristics of plastics that were previously outlined, PET's great chemical and thermal resilience makes it a viable substitute for glass. Mineral water, carbonated drinks, juice, beer, milk, vegetables, and other fresh foods are among the products that have been packaged using polyethylene terephthalate (PET) in a variety of bottles and trays as investigated by Kim, D. J., & Lee, K. T. (2012) and Saeed, L. et al., (2004).

Researchers have demonstrated in their study that long-term usage of plastic bottles or containers raises health risks. Generally speaking, plastic bottles and containers contain a lot of chemicals, many of which pose a major health concern. For instance, it is noteworthy that humans may be exposed to harmful substances as thalates, antiminitroxide, brominated flame retardants, polyfluorinated compounds, and bisphenol A (BPA) as reported by Halden (2010).

Numerous health issues, including ovarian chromosome damage, reduced sperm production, premature puberty, rapid immune system alterations, type-2 diabetes, cardiovascular disease, obesity, and more, have been linked to BPA. According to some research, BPA also raises the risk of metabolic diseases, pain, breast and prostate cancer, and other conditions. Obesity, endometrial hyperplasia, recurrent miscarriages, sterility, and polycystic ovarian syndrome are among the health issues linked to BPA in women as investigated by Rayner et al. (2004) and Eskenazi et al. (2007).

Plastics, especially microplastics, are increasingly recognized as toxic pollutants due to their persistence and bioaccumulation. They carry harmful chemicals and adsorb pollutants like polychlorinated biphenyls (PCBs), pesticides, metals, and polycyclic aromatic hydrocarbons (PAHs) from the environment. These chemicals can leach into organisms, affecting development, physiology, gene expression, and behavior. Factors such as leachates, weathering, and biofilms intensify these effects. Global policies, including a United Nations Environmental Assembly are essential to address plastic pollution's ecological and health impacts as investigated by Weis, J. S., & Alava, J. J. (2023).

Environmental pollutants, whether natural or man-made, harm humans, animals, and ecosystems while integral to human activities. Chemical pollutants (ECPs) and agricultural pollutants (EAPs) affect air, water, and soil, causing diseases like respiratory issues and cancer. EAPs, such as pesticides and fertilizers, disrupt hormones and reduce crop yields, while industrial ECPs like carbon dioxide exacerbate global warming. Mitigation is costly and complex, emphasizing the need for regulation to protect health and ecosystems as reported by Chaitanya, M. et al. (2024).

According to Andrady (2015) the same qualities that make plastic helpful also increase the likelihood that it may harm the environment: it is hydrophobic, lightweight, durable, and affordable to produce.

Microplasticsplastic and its Impact on the Environment

Microplasticsplastic particles smaller than 5 mm—have emerged as a significant environmental concern in recent years. Less research has been done on microplastics in soils and groundwater, despite their widespread presence in marine and lake systems. It was discovered that, in South Korea, greenhouses are the primary source of microplastics, whereas littering is the primary source of microplastics in topsoil worldwide. Fibers and pellets are the most common microplastic forms found in soil and groundwater. The health of people, plants, nematodes, earthworms, and soil qualities are negatively impacted by soil and groundwater microplastic pollution as reported by Chia, R. et al., (2021).

Li et al. (2021) studied that Microplastics have the potential to move vertically through the soil's sublayers and, ultimately, into deeper soil layers once they are deposited on the soil's surface.

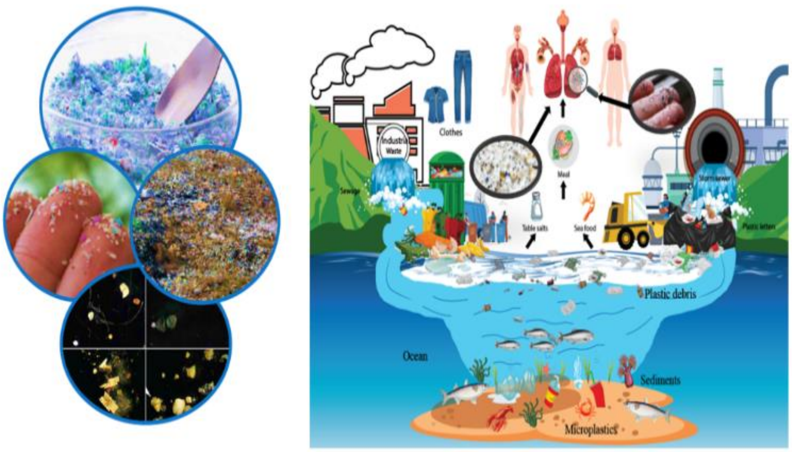

Fig. 2: Microplastic and its Impact on the Environment

Source: https://shorturl.at/Nb6EI

According to Re (2019), when microplastics are added to the soil, they may ultimately seep into the soil's pores or leak into the groundwater system.

Microplastic contamination is also thought to be a result of personal care products. Certain toothpaste, soap, and face scrub products include microplastics that may find their way into aquatic habitats via wastewater treatment facilities as investigated by Napper et al., (2015).

Microplastics resemble phytoplankton which are eaten by fish and cetaceans (Boerger et al. 2010). It has been shown that ingesting plastic waste can induce intestinal obstruction, internal damage, growth retardation, and decreased stomach capacity as investigated by Plot and Georges (2010).

Air, Water, and Soil pollution from plastic production: -

One of the main causes of air pollution is the burning of plastic garbage in an open area. The majority of the time, burning municipal solid waste that contains around 12% plastic releases harmful substances into the atmosphere, including dioxins, furans, mercury, and polychlorinated biphenyls. Additionally, burning plastic releases harmful halogens and pollutes the air, both of which contribute to climate change. The ecosystem as a whole, human and animal health, and plants are all at risk from the hazardous compounds that are so discharged. detrimental to the central nervous system as well. The dangerous brominated chemicals have mutagen and carcinogenic properties as investigated by Verma, R. et al., (2016).

Fig. 3: Burning Plastic and its Impact on the Environment

Source: https://shorturl.at/Xfe2m

According to Blight and Burger (1997) over the past few decades, the amount of plastic pollution that is brought to sea has greatly increased. Wildlife frequently get injuries as a result of ingesting or being entangled in environmental plastics. For Procellariiformes, including petrels, shearwaters, and albatrosses, degraded plastic fragments resemble a lot of the foods they eat.

Microplastics resemble phytoplankton which are eaten by fish and cetaceans (Boerger et al. 2010). Ingested plastic debris has been found to reduce stomach capacity, hinder growth, cause internal injuries, and create intestinal blockage as investigated by Plot and Georges (2010).

The amount of plastic waste in the soil ecosystem is concerning because it can build up in plants grown in polluted soils and have an impact on consumers by getting straight into the food supply chain. The soil ecology and plant development are negatively impacted by plastic pollution in agriculture. People want to know more about how plastic particles impact plant biomass and growth, as well as if plants can take up plastic particles from the soil environment and store them in their root systems as reported by Zhu, F., et al., (2019).

Conclusion

Addressing plastic pollution requires immediate and comprehensive action to mitigate its far-reaching impacts on ecosystems, wildlife, and human health. The persistence of plastics, their degradation into harmful microplastics, and the leaching of toxic chemicals like BPA and phthalates highlight the urgent need for solutions. Combating this issue necessitates a multifaceted approach, including stricter regulations, innovative technologies for sustainable alternatives and recycling, and widespread public awareness campaigns. By collectively reducing reliance on single-use plastics and adopting more sustainable practices, society can work toward minimizing the environmental and health risks posed by plastic pollution.

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11

Methods for Colistin Detection in Biological Matrices: Current State and Future Directions - A Review

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Introduction

Colistin, or polymyxin E, is a last-line antibiotic used against multidrug-resistant (MDR) Gram-negative bacteria such as *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and carbapenem-resistant Enterobacteriaceae (CRE) [1-4]. Initially sidelined due to nephrotoxicity and neurotoxicity, colistin has resurged due to the rise in antimicrobial resistance (AMR). Its unique amphipathic structure, comprising colistin A and B, disrupts Gram-negative bacterial membranes, making it effective against otherwise resistant pathogens [4-11]. Administered as the prodrug colistimethate sodium (CMS), its incomplete conversion complicates dosing, necessitating therapeutic drug monitoring (TDM) to balance efficacy and toxicity [10-13]. Resistance has emerged, driven by *mcr* genes, which alter bacterial lipopolysaccharides. Agricultural misuse has exacerbated this, accelerating resistance gene dissemination and threatening public health [4-11].Accurate colistin detection is vital for therapeutic, agricultural, and environmental management. In healthcare, monitoring plasma levels prevents underdosing, which can lead to resistance, and overdosing, which causes toxicity. In agriculture, detecting colistin residues in animal products and wastewater mitigates its misuse and entry into the human food chain. Environmentally, reducing contamination curbs resistance gene proliferation. Advanced analytical methods are essential for sensitive, specific, and rapid colistin detection across diverse matrices to combat AMR, promote stewardship, and safeguard public health [14-17].This review examines the role of colistin in modern medicine, the challenges in its detection, and advancements in analytical

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technologies, offering insights for researchers, clinicians, and policymakers to enhance its use and address associated risks.

Objective of the Study & Synthesis of the Data

The electronic databases were methodically searched for pertinent published publications. We looked through the associated articles to find other sources of information and data. Combinations of the subject headings "Detection of colistin," "Quantitative detection of colistin," "Method for detection of colistin sulphate," "Detection of colistin A and colistin B with LC-MS/MS," "Sensors for detection of colistin," "Electrochemical detection of colistin," etc. were used to retrieve a subset of studies. The published papers were only available in English. The study includes publications that described procedures for testing colistin on its own or in combination with other compounds in biological samples. After the chosen articles were examined, each original article's whole text was located. The objective of this review article is to gather following information from the selected articles.

- To assess the current status and effectiveness of colistin sulphate detection methods.
- To analyze the accuracy, sensitivity, and practicality of existing approaches.
- To evaluate chromatographic methods (HPLC, LC-MS), biosensors, and electrochemical immunosensors for colistin detection.
- To address challenges such as sample matrix, cross-reactivity, and standardization issues.
- To recommend future directions in colistin detection research, focusing on point-of-care applications, miniaturization, and enhanced specificity.

Results & Discussion

Various techniques are used to detect colistin in different matrices, ranging from traditional microbiological methods like disc diffusion and agar dilution, which are less sensitive for environmental samples, to advanced instrumental approaches. High-Performance Liquid Chromatography (HPLC) offers reliable extraction and quantification of colistin, while Liquid Chromatography-Mass Spectrometry (LC-MS/MS) provides exceptional sensitivity and specificity. Enzyme-Linked Immunosorbent Assay (ELISA) kits offer quick, cost-effective detection using colistin-specific antibodies. Biosensor-based techniques enable real-time monitoring, and other methods like Thin Layer Chromatography (TLC), MEKC-LIF, ATR FTIR, and fluorescent artificial receptors also contribute to colistin detection in biological samples.

Sample Preparation Techniques

The removal of endogenous chemicals from samples is essential in drug assays to prevent interference during liquid chromatography and mass spectrometry detection. The matrix effect, which refers to interference from endogenous substances, can impact analyte response. To ensure clean extracts and adequate recovery, sample preparation methods must be optimized for different biological matrices. Three key techniques for colistin assay sample preparation include protein precipitation with solid-phase extraction (SPE), protein precipitation, and the SPE procedure.[18]

Chromatographic and Hyphenated Chromatographic Techniques

Chromatographic methods, especially hyphenated techniques, are pivotal for the precise and sensitive detection of colistin across complex matrices. High-performance liquid chromatography (HPLC) ensures accurate colistin quantification with excellent repeatability and sensitivity, enhanced by fluorescence or UV-Vis detectors. Liquid chromatography-mass spectrometry (LC-MS) integrates the separation power of liquid chromatography with the molecular specificity of mass spectrometry. LC-MS/MS offers exceptional sensitivity and specificity, enabling simultaneous detection of multiple colistin components even in complex samples. These methods, using optimized columns, flow rates, and mobile phases, are invaluable for clinical diagnostics and environmental monitoring, providing reliable results with low detection limits.

Author	Sample	Analyte	Method Used	Column	Mobile Phase	Flow Rate	Detection Limit	References
Fu et al. 2018	chicken eggs, feed, swine muscles, chicken muscles, Swine liver, bovine muscles, sheep muscles, bovine milk	Colistin A, Colistin B	UHPLC-MS/MS	Acquity BEH C_{18} column (50mm×2.1mm i.d.,1.7μm particle size) (Wates,Milford,MA,USA) where column oven temperature is of 40°C, and injection volume of 5 μL	Mobile phase A-0.5% formic acid in water Mobile phase B- 0.5% formic acid in acet- onitrile	0.4 mL/min with the following gradient program: 0–0.5 min, 95% A; 0.5–3.0 min, 95–50% A; 3.0–4.0 min, 50–5% A; 4.0–4.1 min, 5–95% A; 4.1–5.5 min, 95% A	5-30 μg/kg	5
Yuan et al. 2021	rat plasma, cell culture medium, drug transport media and human epithelial cell lysate	Colistin	HPLC-MS/MS	Kinetex C_{18} (2.6 mm, 100 Å, 50 mm× 3 mm) column (Phenomenex, Los Angeles, CA, USA)	Mobile phase A- 0.1%(V/V)aqueous formic acid Mobile phase B- 0.1%(V/V) formic acid in acetonitrile	Flow rate was 0.4 mL/min where the proportion of phase A (0- 0.5min) was 90%. The proportion of phase B rose to 60% (0.5- 1.0 min),then to 90% (1.5- 2.5min),and was maintained at 90% for 0.5 min. Afterwards, the proportion of phase B decreased to 10% (3.0-3.5 min), and it was maintained until 6 min	**Colistin A;** 0.029 μg /mL **Colistin B;** 0.016μg /mL	19
Morales-Mu˜noz et al. 2005	Animal feed	Colistin	HPLC–fluorescence detector (FLD)	Ultrabase C_{18} (250mm×4.6mm; 5m particle size from Scharlau, Barcelona, Spain)	Mobile phase was 75:25% acetonitrile–water	flow rate of 1.5 ml/min	2.46μg /g	2
Decolin et	Bovine milk	Colistin	HPLC -MS/MS	an analytical column	The mobile phase comprised	The flow	In milk;	20

al. 1997	and tissues (muscle, liver, kidney, and fat)			(125 × 4-mm i.d.) prepacked with 5-µm Nucleosil C_{18} (Macherey-Nagel, Düren, Germany) where the column temperature was 35°C	of acetonitrile and a 0.035M triethylamine solution adjusted to pH 2.5 with phosphoric acid and mixed in 17:83 (v/v) proportions The derivatization reagent consists of 80 mg orthoph-taldialdehyde and was dissolved in 15 mL of methanol, and 15 mL of 0.2M borate buffer with pH 10.5 and 0.1 mL of Merc were added.	rate was 1.5 mL/min	10 µg/L In bovine tissues; 50-100 µg/kg	
Morovjan et al. 1998	Animal feeds	Colistin	HPLC–fluorescence detector (FLD)	TosoHaas TSK ODS 120T column (150 x 4.6 mm ID, 5 µm) with injection volume 25µL	Mobile phase comprised of a 22:78 (v/v) mixture of acetonitrile - 50 mM sodium sulphate, 20 mM orthophosphoric acid, 25 mM triethylamine (pH 2.8) solution For the post-column reagent, 1.6 g orthoph- taldialdehyde was dissolved in 25 mL methanol. The methanolic orthoph- taldialdehyde solution, 20 mL 2-mercaptoethanol and 30 mL 10 % (w/v) Brij-35 was added to 300 mL 0.4 M borate buffer (pH 10.4). The solution was thoroughly mixed, purged with helium for 5 minute to remove dissolved oxygen and was made up to 1000 mL with borate buffer (0.4 M, pH 10.4)	The flow rate of the mobile phase is 1.5 mL/min and flow rate for the post-column reagent was and 1.0 mL/min,	0.1 mg/L	21
Cancho-Grande et al. 2001	Medicated feeds	Colistin	HPLC–fluorescence detector (FLD)	The column (150× 4.6 mm i. d.) used was packed with Ultracarb 5 pm ODS 30% C (Phenomenex, Torrance, CA, USA). The guard column (50 ×4.6mm i. d.) was packed with dry 40 pm Pelliguard LC-18 (Supelco, Gland, Switzerland)	The mobile phase consisted of 75 % acetonitrile and 25% water The derivatization reagent consists of 80 mg orthoph-taldialdehyde and was dissolved in 15 mL of methanol, and 15 mL of 0.2M borate buffer with pH 10.5 and 0.1 mL of Merc were added.	The flow rate was 1.5 mL/min	5mg/Kg	22
Ouchi et al.	Rat plasma	Colistin A, Colistin B	HPLC–fluorescence detector (FLD)	Cadenza CD-C18 column (100 × 4.6mm, 3µm) purchased from Imtakt Co. (Kyoto).	Mobile phase A consisted of acetonitrile–methanol–water–tetrahydrofuran (30:10:35:25, v/v/v/v). Mobile phase B consisted of acetonitrile–methanol–water–THF (55:10:10:25, v/v/v/v).	flow rate was 1mL/min.	For both colistin A & B;0.05 µg/mL	23
Chepyala et al. 2015	Human plasma	Colistin	HPLC–fluorescence detector (FLD)	An Agilent Poroshell 120 EC-C_{18} 2.1 × 100 mm (2.7 µm) column (Agilent Technologies,USA) which is connected to a Atlantis dC_{18} 2.1 × 10 mm (3 µm) guard column (Waters, Ireland) with a was used where the injection volume is 25µL	The mobile phase was composed of ACN, Tetrahydrofuran, and Water (82 %, 2 %, 16 % V/V, respectively).	flow rate was 0.5 mL/min	0.1 µg/mL	24
Clarot et al. 2009	pharmaceutical formulation	Colistin Sulphate	HPLC-evaporative light scattering detection(ELSD)	Zorbax SB C_{18} (Agilent Technologies Inc., Santa Clara, CA, USA) 150mm×4mm i.d., 3.5m reversed phase column. Where the column temperature was controlled with a Croco-Cil external oven (CIL Cluzeau, Sainte Foy la Grande, France) where column temperature was maintained at 30°C	Mobile phase A- mixture of 37.5 mM Trifluoroacetic acid in water Mobile phase B- 37.5mM Trifluoroacetic acid in acetonitrile	Flow rate was 1.0 ml/min		25
Gaugain et al. 2021	Animal feeds (for pigs, poultry and rabbits)	Colistin	LC-MS/MS	A Kinetex biphenyl column (100 mm × 2.1 mm, 2.6 µm) from Phenomenex (Le Pecq, France) and an X-Bridge C_{18} column (150 mm x 2.1 mm, 5 µm) from Waters (Saint- Quentin-en-Yvelines, France) to protect the column where the Mistral column oven temperature was of 30℃ and injection volume is 5 µL.	Mobile phase A- 0.2% formic acid in ultrapure water Mobile phase B- 0.2% formic acid in acetonitrile	Flow rate was 350 µL/min with the following gradient program 95% A from 0 to 1 min, 95–0% A from 1 to 5 min, 0% A from 5 to 6 min, 0–95% A from 6 to 6.1 min and finished with 95% A	0.5 mg/kg	26

						from 6.1 to 8.5 min to equilibrate the column		
Kumar et al. 2021	Chicken muscle and eggs	Colistin B	UHPLC–MS/MS	Hypersil GOLD™C_{18} (100×2.1mm,1.9 µm) from Thermo Scientific, SanJose, USA where the injection volume was 10 µL and column oven and sample manager temperatures were maintained at 40 °C and 8 °C respectively.	Mobile phase A- 1% formic acid in water Mobile phase B- 1% formic acid in acetonitrile	Flow rate was 0.4 mL/min where mobile phase gradient program includes 0–0.5 min, 5% B; 0.5–3 min, 5–50% B; 3–4 min, 50–80% B; 4–5.8 min, 80% B, 5.8–6 min, 80–5% B; 6–9 min, and 5% B phase.	For chichi muscle; 10 µg/ Kg For chichi eggs; 5 µg/Kg	27
Dotsikas et al. 2011	human plasma	Colistin A & B	LC-MS/MS	ACE C-18 (150×4.6 mm, particle size 5mm) where the injection volume was 25µL	Mobile phase consists of methanol and formic acid 0.1% 40:60 v/v	flow rate was 1.2 mL/min		28
Li et al. 2001	human plasma	colistin	HPLC-fluorescence detector (FLD)	C_{18} column (Beckman, Berkeley, CA, USA).	Mobile phase consists of acetonitrile–tetrahydrofuran–water (87:4:13, v/v)	Flow rate was 1ml/min	0.10 mg/ l.	29
Ma et al. 2008	Human plasma and urine, and perfusate and urine from the isolated perfused rat kidney (IPK)	colistin A sulfate, colistin B sulfate	LC–MS/MS	A SynergiFusionRP 2m column (20mm×2.0mm, Phenomenex, Torrance, CA, USA) equipped with a guard column (Phenomenex, Torrance, CA, USA)	The mobile phase consists of acetonitrile, water and acetic acid (80/19/1, v/v/v)	Flow rate was 0.2mL/min	For human plasma, IPK perfusate and urine – **Colistin A sulfas;** 0.028µg/mL **colistin B sulfas;** 0.016 µg/mL in human urine- **Colistin A sulfas;** 0.056 µg/mL **colistin B sulfas**; 0.032 µg/mL	30
Mercier et al. 2014	Human plasma	Colistin	Hydrophilic Interaction Liquid Chromatography (HILIC) -MS/MS	HPLC Xbridge BEH-Amide (50 × 2.1 mm, 2.5 µm) HILIC	Mobile phase A- 10mM Ammonium formate in water-0.4% formic acid Mobile phase B-Acetonitrile-0.1% formic acid	Flow rate was 0.3 mL/min	For **Colistin A;** 0.006 µg/mL For **colistin B;** 0.003 µg/mL	31
Pinho et al. 2018	Human plasma	colistin	HPLC-fluorescence detector (FLD)	LiChroCART® Purospher Star® C18 column (55 mm×44 mm, 3 µm particle size from Merck KGaA, Darmstadt, Germany) where column temperature is 30°C	Mobile phase A- Acetonitrile Mobile phase B-Water	Flow rate at different time interval: **0-4 min -** 0.7 mL/ min **4-5min-** 1.0 mL/min **5-12 min-** 1.0 mL/min **12-13 min-** 0.7 mL/min **13-17 min-** 0.7 mL/min	0.09 µg/mL	32
Hanai et al. 2018	Human plasma	colistin	HPLC-fluorescence detector (FLD)	A reverse-phase Hydrosphere C18 column (internal diameter [i.d.], 4.6×50 mm, 5 µm), which was purchased from YMC Co., Ltd. (Kyoto, Japan) where column temperature is 40ºC	Mobile phase consist of acetonitrile/tetrahydrofuran/distilled water (50,14,20, v/v/v)	Flow rate was 1.6 mL/min.	0.1 µg/mL	33
Van den Meersche	Swine manure	Colistin A	UHPLC–MS/MS	Kinetex C18column (100 mm x2.1 mm i.d., 1.7	Mobile phase A- H2O/MeCN (95/5) + 0.5% FA + 0.1%	Flow rate was 400	**Colistin A;** 20.2 µg/kg	34

et al. 2016		Colistin B		_m) with a SecurityGuard Ultra guard cartridge sys-tem (Phenomenex, The Netherlands, Utrecht).Where the column tem,perature was 30ºC,and the injection volume was 5µL	ammonium formate Mobile phase B- MeCN + 0.1% FA	µL/min	**Colistin B;** 15.0 µg/kg	

Enzyme-linked Immunosorbent assay (ELISA) and Electrochemical Detection of Colistin in Biological and Environmental Samples

Colistin detection has evolved with advanced methods like ELISA, biosensors, and electrochemical immunosensors. ELISA techniques, including competitive and indirect formats, are widely used due to their sensitivity and adaptability. Wang et al. (2019) developed an ELISA with an IC50 of 9.7 ng/mL and LFIA with a detection limit of 0.87 ng/mL, both achieving recovery rates of 77.83–113.38%[35]. Galvidis et al. (2020) and Burkin et al. (2022) further refined ELISA sensitivity for colistin in milk, eggs, and other matrices, achieving detection limits as low as 0.3 ng/mL[36,37]. Biosensors, like the SERS-based immunosensor by Li et al. (2018), achieved a 0.10 ng/mL detection limit in milk within 20 minutes[39]. Y. Li et al. (2020) created a portable LFIA for simultaneous colistin and bacitracin detection with a limit of 1.89 ng/mL[40]. Electrochemical immunosensors, such as Kumar et al.'s (2022) amperometric design, recorded colistin at 0.89 µg/kg in chicken liver using CNF/AuNPs-modified electrodes[42]. Biosensors demonstrate quick, targeted detection, supporting ethical antibiotic use and resistance monitoring. These advancements provide reliable, sensitive tools for detecting colistin in clinical, agricultural, and environmental samples, crucial for antibiotic surveillance[35-42].

Some other Techniques for Colistin Detection in Biological and Environmental Samples

Various innovative methods have been developed for colistin detection. Microbiological assays assess colistin's efficacy through bacterial growth inhibition, using methods like disc diffusion and agar dilution to determine susceptibility and minimum inhibitory doses[43-49]. Lopez et al. (2022) created a microbial bioassay utilizing *Geobacillus stearothermophilus* with a glucose-based metabolic readout, achieving growth suppression detection at 8 µg/L of colistin [50]. Hasan et al. (2021) used thin-layer chromatography (TLC) to detect colistin residues in broiler chicks, showing 100% residue detection in organs from indiscriminate antibiotic use groups [51]. Ahmed et al. (2012) employed mixed surfactant micellar electrokinetic chromatography-laser-induced fluorescence (MEKC-LIF) with fluorescein isothiocyanate derivatization, achieving a detection limit of 100 ng/mL in urine samples [52] . ATR-FTIR spectroscopy, as described by Niece et al. (2015), enabled direct detection of colistin methanesulfonate (CMS) in plasma without interference, with sensitivity down to 50 µg/mL [53]. Turan et al. (2020) developed fluorescent artificial receptors using graphene quantum dots with a detection limit of 7.3 ng/mL in human blood, demonstrating high specificity and recovery rates of 93.8–105%[54]. These diverse techniques highlight significant advancements in colistin detection for clinical, agricultural, and environmental applications.

Challenges and Future Prospect in Colistin Detection

Detecting colistin faces significant challenges, including complex sample matrices like environmental and clinical specimens, which introduce interfering compounds affecting specificity and sensitivity. Variations in methodologies across laboratories further complicate standardization, leading to inconsistent results. Data interpretation is hindered by false positives, negatives, and cross-reactivity with structurally similar molecules. The emergence of resistance genes, such as *mcr-1*, underscores the need to continually adapt detection methods to evolving resistance mechanisms. Addressing these challenges is essential to maintain colistin's efficacy, understand resistance patterns, and promote antibiotic stewardship. Despite these hurdles, advancements in analytical techniques offer a promising future. Innovations in biosensors, such as electrochemical and optical platforms, provide rapid, sensitive, and targeted colistin detection for applications like clinical diagnostics and environmental monitoring. Integrating AI and machine learning can enhance data analysis in large-scale colistin surveillance. Genomic and molecular advancements are paving the way for sophisticated tests to identify specific resistance genes and unravel the genetic basis of colistin resistance. Miniaturization and point-of-care technologies could enable decentralized, real-time testing. With multidisciplinary research driving progress, future colistin detection methods promise to be more reliable, adaptable, and globally applicable, supporting antibiotic stewardship and combating rising antibiotic resistance effectively.

Conclusion

To sum up, this review provides a comprehensive analysis of colistin detection methods, emphasizing the importance of accurate and timely studies amidst growing antibiotic resistance. It covers a range of techniques from traditional microbiological tests to advanced biosensors, chromatographic methods, and molecular approaches. Despite recent advancements, challenges such as standardization, evolving resistance mechanisms, and sample matrix variability persist. Future innovations in biosensors, genomics, and artificial intelligence offer promise for better monitoring and control of colistin use. These advancements aim to preserve the effectiveness of colistin, ensuring its role in combating antibiotic resistance for global public health.

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