Emerging Technologies in Chemistry for the Environmental Sustainability

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Abstract: - Chemists in all corners of the world have made exceptional contributions to science through innovative technologies and innovations in their research fields. A team of IUPAC experts has already begun to identify emerging technologies in Chemistry that could make our planet more sustainable. MOFs and porous materials for water harvesting, nanopesticides, 3D bioprinting, dual-ion batteries, macromonomers for better plastic recycling, nanosensors, artificial intelligence, high-pressure inorganic chemistry, flow chemistry, and reactive extrusion are among the most important chemical innovations. Water scarcity affects more than 40 percent of the world population, and it is projected to rise. Porous materials, such as metal organic frameworks (MOFs), could provide a solution to this problem, according to the United Nations (UN). Porous materials such as MOFs have a sponge-like chemical structure with microscopic spaces that can selectively trap molecules from gases hydrogen, methane, carbon dioxide, water, to more complex substances such as drugs, and enzymes. Some researchers accidentally discovered that MOFs have an incredible ability to capture water from the atmosphere. Nanopesticides are an alternative to conventional pesticides, as they can be used as "smart delivery systems" for the release of pesticides in a timely, but controlled fashion, for a desired timeframe. Chemists use radical ring-opening reactions to add heteroatoms and functional groups, such as ester, to structures, which traditionally have an all-carbon backbone, are hydrolysed for better plastic recycling.

Key Words: — ***Emerging Technologies, Sustainable Environment, Metal-organic frameworks, Water harvesting, Nanotechnology, Plastic Recycling.***

I. INTRODUCTION

International Union of Pure and Applied Chemistry (IUPAC) have initiated for giving scientific credit to innovative chemical innovations since 2019 as the year was famous for two major anniversaries: the 100th anniversary of the founding of the International Union of Pure and Applied Chemistry (IUPAC), and the 150th anniversary of Dimitri Mendeleev's first publication on the Periodic Table of Elements [1-3]. Ten chemical innovations that will change our world and make the environment more sustainable have been pointed in last two years. The 2019 top ten were nanopesticides, enantio-selective organocatalysis, solid-state batteries, flow chemistry, reactive extrusion, metal organic frameworks (MFOs), directed evolution of selective enzymes, turning plastics to monomers, reversible deactivation of radical polymerization, and 3D-bioprinting [1,3]. The 2020 top ten were aggregation-induced emission, artificial intelligence applied to chemistry, dual-ion batteries, high-pressure inorganic chemistry, liquid gating technology, macromonomers for better plastic recycling, microbiome and bioactive compounds, nanosensors, rapid diagnostics for testing, and RNA vaccines [2,3]. The "Top Ten Emerging Technologies in Chemistry" is a research effort to more widely highlight the chemical and related sciences' essential value and to identify discoveries that could change our world. These innovations were selected on the basis of their ability to open up new fields in chemistry and beyond, and in between a new scientific discovery and a fully commercialized technology. The innovative "Top Ten Emerging Technologies in Chemistry" for the current year is still awaited. In this paper the most important innovations such as MOFs and porous materials for water harvesting, nanopesticides and macromonomers for better plastic recycling have been briefly discussed.

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Chemistry plays a pivotal role in our ability to adapt to a changing and ever-growing world, but chemicals can also cause trouble if they are used incorrectly or in the wrong environment. One should be clear on how chemicals interact with the environment, whether they will naturally degrade, and how they will be contained and disposed of. Chemical innovations can make our environment more sustainable. Therefore, the changing technology paradigm and challenging of the status quo is becoming increasingly apparent because of growing global economic competitiveness, social inequalities, and the scale of environmental problems. Environmental innovations are crucial to reducing environmental impacts and resolving the environment-versus- economic conflict, and chemistry plays a significant role in supporting these innovations. These innovations may be designed to reduce a specific adverse environmental effect, for example, in response to regulations, or their benefits can be the result of the environmental components of other types of innovations [4].

II. *MOFS AND POROUS MATERIALS FOR WATER HARVESTING*

The crisis of drinkable water is a major concern for the world's population, which is attracting the attention of researchers and has now become a cornerstone of environmental chemistry research [5-7]. Researchers are trying to solve this problem in air water harvesting in an inexpensive manner. Materials that can reversibly adsorb and desorb water are highly intriguing from this perspective. Nature has however already come up with the concept of harvesting water from atmospheric humidity in geographical areas where water availability is extremely limited. Limited access to freshwater due to the absence of sources such as lakes, rivers, and groundwater is already creating problems, with many of these sources becoming contaminated by human activities. Traditional methods for obtaining clean water, such as reverse osmosis and distillation, are expensive and energy-intensive, which reduces their real-world use [8]. Therefore, it is essential to find portable, straightforward and low-cost ways to generate clean water on demand in different environments. A substantial effort on tapping non traditional water resources, such as atmospheric water vapor, focuses on the ability to supply freshwater on demand virtually anywhere on the earth. Atmospheric water harvesting offers an attractive alternative, as it can be used off the grid and in virtually any environment to tap into the omnipresent water vapor in the Earth’s atmosphere [8]. Metal organic frameworks (MOFs) are promising tools that can act as adsorbents to collect airborne water to address the water shortage in arid areas around the world. MOFs are an extremely versatile class of adsorbents, since they are made of inorganic clusters (or secondary building units, SBUs) and organic molecules (‘linkers') in order to form robust, crystalline, and permanently porous framework structures [7]. Several SBUs, linker molecules, and network topologies can be employed in MOFs, providing a high degree of chemical and structural tinkering and the ability to tailor their properties to a multitude of industrial applications. Some of these materials can also be used for large gas and vapour uptakes due to their ultra-high porosity [7]. In the literature, the adsorption/desorption mechanism in different MOFs has been described in order to determine the role of functionalities and hydrophilicity, in addition to water adsorption isotherms that provide indication of the performance of an adsorbent with respect to the adsorption/desorption cycle. Also, structural and compositional factors, such as organic ligands, metal nodes and defects, that are required to alter MOFs' adsorption and desorption behaviours and to increase their adsorbent's working capacity, have been taken into account. Omar Yaghi discovered their great potential for capturing water from the atmosphere accidentally when he was studying the trapping of post-combustion gas uptake into MOFs [1]. He says that some MOFs have a unique interaction with water molecules. They then wondered whether the same material could be used to trap water from the atmosphere in arid climates and then release it easily for collection. This technology is unique, because it can harvest drinkable quantities of pure water from the dry desert air without any additional energy than the natural sunlight [9]. Yaghi already tried with companies to test their MOF water harvesters on an industrial scale. There are other porous materials with similar properties, such as silica-based and inorganic porous solids, and recently reported biomimetic porous surfaces that mimic the structure of cactus spines. However, they are not as effective at capturing water from low humidity air.

Generally, conventional reaction is normally carried out in liquid phase by mixing organic ligands, metal SBU, and a solvent for a set period of time, after which it is filtered and dried by evaporation to produce a purified MOF [10,11]. Hydrothermal/solvothermal synthesis is the most common way to synthesize MOFs via conventional electrical heating at a set temperature. Dimethyl formamide, diethyl formamide, acetonitrile, acetone, ethanol, or methanol solvents are used in this method. Besides, microwave-assisted, sonochemical, electrochemical, mechanochemical, ionothermal, drygel conversion, and microfluidic synthesis methods also employed for synthesis MOF.

III. NANO PESTICIDES

The world population is growing at an alarming rate, and people worldwide are involved in agriculture for the production of essential food crops and many other commodities such as fuels, fibres, and raw materials [12]. In view of the scarcity of natural resources (e.g., land, soil, water, etc.) and crop yield limitations, as well as contemporary agricultural pest and pathogen control methods lead to the release of 90 percent of the pesticides into the air and the ground, affecting both farmers and the environment [13,14]. Moreover, the indiscriminate use of pesticides can increase pest and disease resistance, reduce nitrogen fixation, reduce soil biodiversity, and increase pesticide bioaccumulation [15]. These are significant issues that require careful consideration in order to reduce costs for stakeholders, improve productivity, increase efficiency, and reduce environmental impact. Therefore, advanced agricultural methods that are economically and environmentally feasible are increasingly in demand [16]. The application of nanotechnology-based pesticide concepts, known as nanopesticides, is expected to address these problems by increasing pesticide efficacy, reducing dose requirements, increasing the stability of payloads delivered from the environment and subsequently reducing runoff and addressing environmental concerns. Nanopesticide is a two to three dimensional nanostructures which confers pesticidal properties or contains active ingredients of a pesticide in nanoform. These nano structures have long been observed to have a slow degradation rate and controlled release of the active ingredient [17]. Nanopesticides have the above-mentioned properties, making them less toxic and less dangerous than chemical pesticides. The rapid development of nanopesticides has inspired researchers to develop nanopesticides that are less harmful to the environment, as well as targeting-specific, without sacrificing their effectiveness [16].

Target-specific nanopesticides should therefore help to reduce damage to non-target plants and the amount released into the surrounding environment. Thus, the encapsulation of pesticide active ingredients within nanoparticles is a promising approach for the development of novel nanopesticide based formulations. It involves three major strands, including improved conventional pesticide formulations, new delivery systems using nanoparticles as nanocarriers, and solid nanoparticles as active pesticide agents [13]. Nanopesticides needs to be assessed properly as this development will likely face a rigorous review by international and national safety regulations that will require more research on the impact of these materials on the environment and humans. Some companies continued to test their potential, proving there is still hope for this technology. Canadian Vive Crop is perhaps the best example, as its products have shown better absorption and less environmental damage than their non-nano commercial counterparts. Moreover, this company recently received approval from the U.S. Environmental Protection Agency to commercialize several nano-encapsulated insecticides and fungicides [1].

IV. MACRO MONOMERS FOR BETTER PLASTIC RECYCLING

Plastics are now the most widely used man-made materials and are present in every aspect of our lives from medical supplies and water bottles to food packaging, clothing and construction materials [18]. Each year, plastic production increases 20-fold since the 1960s, reaching 335 million tons in 2016. It is predicted to rise to over 1.12 billion tons in 2050 [19]. However, current unsustainable practices in the production and disposal of plastics continue to deplete our finite natural resources and cause dire environmental consequences. Chemistry can provide practical solutions for recycling plastics that we currently use and, over the long-term, create replacements that are made from sustainable starting materials, are more flexible to recycling at the end of their life, and degrade more quickly to harmless by-products. Many research groups are trying to develop new methods for recycling the most abundantly produced plastics. Redesigned monomers and macromonomers are an emerging strategy to create more sustainable plastics [2]. Chemists rely on radical ring-opening reactions as radical ring opening polymerization process for cyclic monomers seems particularly attractive, as it has both the advantages of ring opening polymerization and radical polymerization, that is, the production of polymers with heteroatoms and/or functional groups in the main chain while a radical process provides robustness, simplicity, and mild polymerisation conditions [20].

Recently, several groups have optimized this technology, resulting in a broad range of biodegradable plastics that maintain the attractive properties of conventional polymers [2, 21]. These techniques are not yet widely used, but chemists are heading in the right direction, re-thinking polymers and developing structures that ensure recycling.

V. Conclusion

The IUPAC 47th World Chemistry Congress marked the 100th anniversary of IUPAC and the 150th anniversary of the Periodic Table of Chemical Elements in 2019. The congress highlighted how chemistry addresses today's most pressing issues that affect human health and sustainable development. They started to select top ten chemical innovations that will change our world more sustainable. MOFs and porous materials for water harvesting, nanopesticides and macromonomers for better plastic recycling are the most important chemical innovation for the environmental sustainability. Scientists from all over the world are showing their novel approaches to tackle global environmental challenges. metal–organic frameworks (MOFs) are promising for delivering drinking water to arid regions of the world. Nanopesticides have the potential to reduce the toxic effects of chemical pesticides and provide target-specific control of crop pests. They could be used to develop intelligent nano systems for minimising adverse effects on agriculture, such as environmental imbalance, food security, and food productivity. Plastic recycling will be effortless by using macromonomer in which radical ring-opening reactions facilitate to hydrolyse for better results.

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