ORGANIC CHEMISTRY AND CIRCULAR ECONOMY: OPPORTUNITIES FOR UPCYCLING AND WASTE REDUCTION

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INTRODUCTION

The circular economy is a system of production and consumption that aims to keep resources in use for as long as possible, extracting the maximum value from them , and minimizing waste.It serves as a substitute for the conventional linear economy model , which is predicted on the "take, manufacture ,dispose" method of resource management. A circular economy uses renewable resources wherever feasible and keeps material in use by recycling, remanufacturing, and refurbishing them.[1]

The concept of the circular economy originated from the idea of industrial eco-development, which emphasizes the importance of achieving a balance between economic development and environmental protection , through a "win -win" approach[2]. In this regard, the circular economy aims to minimize the use of resources during the production process, while also promoting the adoption of cleaner technologies. [3]

By embracing the principles of the circular economy, businesses can achieve sustainable economic, social, and environmental development, which will lead to increased profitability and a competitive advantage in the marketplace. In other words , aligning business practices with the circular economy philosophy will enable organizations to achieve sustainable growth while simultaneously maximizing their economic, social, and environmental benefits.[4]

The circular economy has the potential to boost innovation, strengthen economic resilience, and open up new business possibilities. According to a World economic forum report , making the switch to a circular economy may have a $4.5 trillion positive economic impact by 2030.[5] The circular economy may also lessen reliance on expensive or precious resources, such rare earth metals, and lower the risk of supply chain disruptions by encouraging the reuse and recycling of products.

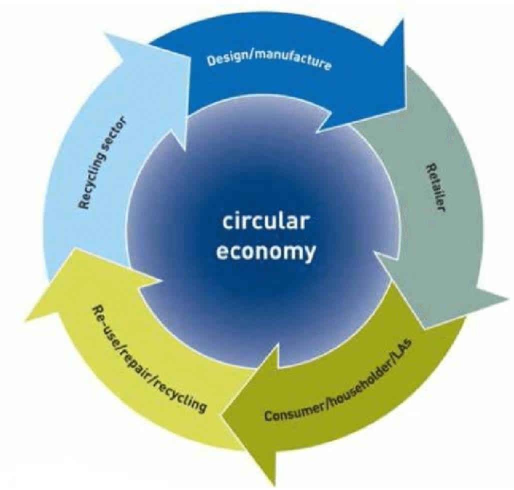

Fig 1: Circular Economy concept

One of the main obstacles of a circular economy is the requirement to transform low economic value trash into high value goods while simultaneously establishing a technology that is globally less expensive than the comparable virgin fossil resource. There is no question that the chemist will be able to contribute to the creation of new methods using this sort of technique.[6]

ROLE OF ORGANIC CHEMISTRY IN CIRCULAR ECONOMY

By facilitating the conversion of waste materials into useful chemicals and materials , organic chemistry plays an important part in the circular economy. The key tenets of the circular economy are to minimize waste and increase resource utilization, and this transformation aids in both of those goals.

One of the main ways in which organic chemistry contributes to the circular economy is through the development of waste bo-refinery systems from municipal solid trash to reduce extra expenses and environmental effects associated with biomass production, collecting, and harvesting. These systems are now mostly focused on waste from the agro-food business.[7] Biorefineries transform organic waste into high-value chemicals and materials, such as biofuels, bioplastics, and biochemicals. Organic waste includes food and agricultural waste. These procedures not only cut waste and the use of non-renewable resources,but they also give the chemical industry a sustainable source of feedstocks.

Another way is through the development of chemically recycling technologies,which involves dissolving wasted plastics into its individual monomers or other chemicals so that they may be utilized as feedstocks to create new plastics or other chemicals.[8] In addition to tackling the problem of plastic pollution , chemical recycling serves to reduce waste and the usage of non-renewable resources.

Clark and colleagues [9] reported the role of chemists in a world where waste is eliminated.They suggested that chemistry can enable the circular economy by creating innovative products from renewable sources that can be reused, recycled, or naturally renewed. Nonetheless, the intricacy of chemical compounds can make recycling and sustainable manufacturing more challenging.[10] To address this issue, they proposed 15 principles that integrate chemistry into a circular economy. These principles aim to minimize molecular complexity , design products with recycling in mind, maintain traceability ,simplify processes, and develop circular metrics.

- **Keep molecular complexity to the minimum** required for the desired performance, including end-of-life.
- **Design products for recycling,** including all additives and other components of the product.
- **Reduce and simplify diversity and dynamics** of substance, material, and product flows and adapt innovation speed of products to adaptation speed of recycling.
- **Avoid complex products**.
- **Minimize use of product components** that cannot easily be separated and recycled.
- **Design products** not suitable for capture and recycling for complete fast mineralization at the end of their lives.
- **Prevent raw materials** from becoming critical through reduced use and efficient recovery and recycling.
- **Avoid entropic losses and transfers**.
- **Avoid rebound effects**.
- **Be responsible for/develop ownership of your product** throughout its complete life cycle, including recycling.
- **Ensure traceability** and consider use of product digital passports.
- **Develop and apply circular metrics**.
- **Change traditional chemical practices** based on "bigger-faster" into "optimal adapted-better-safer" and change ownership to rent, lease, and share business models.
- **Keep processes as simple as possible** with a minimum number of steps, auxiliaries, energy, and unit operations.
- **Design processes for optimal material recovery** of auxiliaries, unused substrates, and unintended by-products.

Fig 2: The fifteen recommendations to integrate chemistry into a circular economy proposed by Clark et. al

UPCYCLING AND ITS IMPORTANCE IN CIRCULAR ECONOMY

Upcycling is the practice of renovating or reusing waste materials or products in order to produce something more valuable or of higher quality . Reducing and reuse are two of the three R's that are aided by upcycling.by enhancing the product's worth , it is a creative and ingenious technique to give outdated or undesirable goods and materials a new life. By prolonging the lifespan of materials , upcycling diminishes the amount of garbage that is dumped in landfills

each year and lowers CO_2 emissions. It also lessens the need to produce new or raw materials,which minimizes the production of greenhouse gasses, water pollution, and air pollution.

The circular economy , which attempts to reduce waste, reuse goods , recycle materials,includes upcycling as a key strategy to keep resources used for as long as feasible. For instance, used plastic bottles may be repurposed into furnishing , building materials,or clothing. Worn garments may be turned into new accessories , luggage, or fashion items. Food scraps may be recycled to make fertilizer or animal feed. There are countless chances, and upcycling can result in new enterprises and employment prospects.

In recent years, there have been a number of successful upcycling instances in organic chemistry that have attracted notice.Here are few examples,

- Upcycling of waste cooking oils into biodiesel and surfactants[11]: Waste cooking oil may clog sewage systems and leak toxic compounds into the environment, making it a serious environmental hazard. Waste cooking oil can be recycled into biodiesel and surfactants. It may, however, also be recycled and turned into usable goods. Researchers have created a method for turning waste cooking oil into surfactants, which are used in detergents and other goods, as well as biodiesel, via a series of chemical events, the waste oil is disassembled into its components and then put back together to create valuable goods.

- Upcycling of waste polyethylene into carbon nanotubes[12]: Waste polyethylene is a significant environmental issue since it ma release dangerous chemicals into the environment and take hundreds of years to breakdown. It may also be recycled into priceless carbon nanotubes, which have several commercial and scholarly uses.Researchers have created a method that heats waste polyethylene in the presence of a catalyst, turning it into carbon nanotubes. The procedure is quite easy and inexpensive, and it has the potential to turn used polyethylene into useful resources.

FUTURE OUTLOOK OF ORGANIC CHEMISTRY IN CIRCULAR ECONOMY

By decreasing the use of non-renewable resources, enhancing resource usage efficiently, and lowering waste, organic chemistry may support the circular economy by creating new technologies and processes. The creation of bioplastic is one instance of how organic chemistry supports the circular economy.As bioplastics may be recycled or biodegraded and manufactured from renewable materials like sugarcane and corn starch, they can replace traditional plastics that are made from non-renewable resources and cannot decompose. Moreover, the usage of bioplastics may help reduce greenhouse gas emission and reliance on fossil fuels.

There have been proposed Five different levels of how chemistry can contribute to the circular economy. The first level involves the use of green chemistry and eco-friendly processes to minimize the negative impact of chemistry on the environment. The second level includes simplifying synthesis and reducing product complexity through closed loops of production chains and optimized resource efficiency. The third level focuses on innovations, new technologies, new methods of valorization, and new concepts. The fourth level entails systematic and more comprehensive environmental and economic assessment, including the use of laboratory scale life cycle assessments. Lastly, the fifth level takes into account local and global issues and opportunities and employs a multi-partner and multidisciplinary approach.

CONCLUSION

Circular chemistry adopts a comprehensive approach, where chemical processes are designed to be circular, allowing products to be repurposed repeatedly with only energy as the input. By developing new chemical reactions to recycle molecules and materials, the chemical sector has

the potential to play a significant role in mitigating scarcity and environmental crises caused by inadequate waste management. The implementation of life cycle thinking and circularity as fundamental principles for developing novel chemical products and processes will enable a closed-loop chemical industry. In summary,organic chemistry and the circular economy can work together to create a more sustainable future by minimizing waste, reducing environmental impact , and promoting economic growth.

Reference

1.Ellen MacArthur Foundation(2021).What Is Circular Economy?
https://www.ellenmacarthurfoundation.org/circular-economy/concepthttps://www.ellenmacarthurfoundation.org/circular-economy/concept

2. Geng, Yong, Jia Fu, Joseph Sarkis, and Bing Xue. 2012. “Towards a National Circular Economy Indicator System in China: An Evaluation and Critical Analysis.” *Journal of Cleaner Production* 23(1): 216–24. http://dx.doi.org/10.1016/j.jclepro.2011.07.005.

3. Andersen, Mikael Skou. 1999. “Governance by Green Taxes: Implementing Clean Water Policies in Europe 1970–1990.” *Environmental Economics and Policy Studies* 2(1): 39–63.

4. Li, Shulin. 2012. “The Research on Quantitative Evaluation of Circular Economy Based on Waste Input-Output Analysis.” *Procedia Environmental Sciences* 12(Icese 2011): 65–71.

5. World Economic forum.(2014). Towards the circular economy: Accelerating the scale-up across global supply chains

6. Chatel, Gregory. 2020. “Chemists around the World, Take Your Part in the Circular Economy!” Chemistry - A European Journal 26(44): 9665–73.

7. Iaquaniello, Gaetano et al. 2018. “Waste to Chemicals for a Circular Economy.” *Chemistry - A European Journal* 24(46): 11831–39.

8. Jambeck Jenna R et al. 2015. “Plastic Waste Inputs from Land into the Ocean.” *Science* 347(6223): 768–70.http://www.scopus.com/inward/record.url?eid=2-s2.0-84954204572&partnerID=40&md5=28a97ef4a4fdee6db9ef2fe507a1a02a.

9. J. H. Clark, T. J. Farmer, L. Herrero-Davila, J. Sherwood, Green Chem. 2016, 18, 3914-3934.

10. Kümmerer, Klaus, James H. Clark, and Vânia G. Zuin. 2020. “Rethinking Chemistry for a Circular Economy.” *Science* 367(6476): 369–70.

11. Zhang, Y., M. A. Dubé, D. D. McLean, and M. Kates. 2003. “Biodiesel Production from Waste Cooking Oil: 2. Economic Assessment and Sensitivity Analysis.” *Bioresource Technology* 90(3): 229–40.

12. Singh, N. B., Singh, R. P., & Pant, H. J. (2018). Upcycling of waste polyethylene into carbon nanotubes. Journal of Environmental Chemical Engineering, 6(5), 5985-5990