OPEN ACCESS
Research of Scientia Naturalis
Vol. 2 No. 3. June 2025, pp. 102-111 DOI. 10.70177/scientia.vxix.xxx

Research Article

The Role of Organic Chemistry in the Development of Biodegradable Polymers

Bilal Aslam [1], Ahmed Shah [2], Rustambek Sharipov [3]
[1] Lahore University of Science and Technology (LUST), Pakistan
[2] Aga Khan University, Pakistan
[3] Tashkent State Economic University, Uzbekistan

Corresponding Author:

Bilal Aslam,
Lahore University of Science and Technology (LUST), Pakistan
College Road, Township, Lahore, Punjab, Pakistan
Email: bilalaslam@gmail.com

Article Info
Received: March 10, 2025
Revised: June 8, 2025
Accepted: June 8, 2025
Online Version: June 8, 2025

Abstract
The increasing environmental concerns associated with plastic waste have prompted significant interest in biodegradable polymers. Organic chemistry plays a crucial role in developing these materials, facilitating the design of polymers that can efficiently degrade in natural environments. This study aims to explore the contributions of organic chemistry to the synthesis and characterization of biodegradable polymers. The focus is on understanding how chemical principles can be applied to create materials with improved degradation rates and functional properties. A comprehensive literature review was conducted, analyzing various biodegradable polymers synthesized through organic chemistry techniques. Experimental work involved synthesizing selected polymers, including polylactic acid (PLA) and polyhydroxyalkanoates (PHA), and evaluating their physical and chemical properties through characterization methods such as spectroscopy and thermal analysis. Findings indicate that organic chemistry enables the tailored design of biodegradable polymers with enhanced properties. The synthesized PLA and PHA exhibited favorable degradation profiles and mechanical strengths, demonstrating their applicability in various fields, including packaging and biomedical applications. This research highlights the essential role of organic chemistry in advancing the development of biodegradable polymers.

Keywords: Biodegradable Polymers, Chemical Properties, Organic Chemistry

Journal Homepage	https://journal.ypidathu.or.id/index.php/scientia
How to cite:	Hamidi, S. A., Hashimi, F. U., & Rahmati, A. (2024). Integrating Artificial Intelligence in IoT Systems: A Systematic Review of Recent Advances and Application. *Research of Scientia Naturalis, 2*(2), 102–111. https://doi.org/10.70177/scientia.v2i3.2012
Published by:	Yayasan Pendidikan Islam Daarut Thufulah

INTRODUCTION

Significant gaps persist in the understanding of how organic chemistry can be further utilized to enhance the properties of biodegradable polymers (Jiang et al., 2020). While considerable progress has been made in synthesizing these materials, challenges remain regarding their mechanical strength, degradation rates, and overall performance in various environmental conditions. Identifying specific organic chemistry techniques that can improve these aspects is crucial for advancing the field of biodegradable materials (Shang et al., 2020).

The long-term stability and performance of biodegradable polymers in real-world applications are still inadequately addressed (Wang, Rao, et al., 2020). Many existing studies focus on laboratory conditions that do not fully simulate the complexities of natural environments. Understanding the interactions between biodegradable polymers and different environmental factors, such as moisture, temperature, and microbial activity, is essential for developing reliable materials suitable for commercial use (Huang et al., 2020).

Additionally, the scalability of organic synthesis methods for producing biodegradable polymers remains a significant barrier. While laboratory-scale successes have been documented, translating these methods to industrial-scale production poses challenges related to cost and efficiency. Exploring innovative synthetic routes and optimizing existing processes will be vital for making biodegradable polymers commercially viable (Mahdi et al., 2022).

Finally, the potential for incorporating bio-based feedstocks into the synthesis of biodegradable polymers is an area that requires further investigation (Chen et al., 2021). While some progress has been made, the full spectrum of available bio-resources has yet to be comprehensively explored. Understanding how organic chemistry can effectively utilize these renewable resources will be key to developing sustainable alternatives to conventional plastics (Daellenbach et al., 2020).

Research has established that biodegradable polymers offer a promising solution to the growing problem of plastic waste in the environment (Ren et al., 2020). These materials are designed to break down into natural substances over time, minimizing their impact on ecosystems. Organic chemistry plays a pivotal role in the development and synthesis of these polymers, enabling the creation of materials that can meet both functional and environmental requirements (Wei & Algeo, 2020).

The fundamental principles of organic chemistry underpin the processes used to design biodegradable polymers (Motes et al., 1998). Techniques such as polymerization, functionalization, and copolymerization allow chemists to tailor the properties of these materials. This ability to manipulate molecular structures is crucial for enhancing biodegradability while maintaining desirable mechanical and thermal properties (Kaspar & Tamplin, 1993).

Many biodegradable polymers, such as polylactic acid (PLA) and polyhydroxyalkanoates (PHA), have been extensively studied (Oliver, 2013). These materials exhibit favorable degradation profiles, making them suitable for various applications, including packaging and biomedical devices. Their production from renewable resources further aligns with sustainability goals, showcasing the potential of organic chemistry to address environmental challenges (Grattan et al., 2016).

The role of catalysts in the synthesis of biodegradable polymers has also gained attention. Catalytic processes can significantly influence polymer characteristics, such as molecular weight and distribution. Understanding how different catalysts affect polymerization reactions is essential for optimizing the production of high-performance biodegradable materials (Guo et al., 2021).

Current advancements in organic chemistry have led to the exploration of new monomers derived from renewable resources (De Araújo et al., 2021). This shift towards bio-based feedstocks not only enhances the sustainability of biodegradable polymers but also opens avenues for innovation in material design. Research in this area is expanding, with a focus on discovering novel monomers that can improve the properties of biodegradable polymers (Ren et al., 2020).

Overall, the interplay between organic chemistry and polymer science is crucial for advancing the development of biodegradable materials (Luo et al., 2022). Continued exploration and innovation in this field are essential for creating effective, environmentally friendly alternatives to conventional plastics, ultimately contributing to a more sustainable future (Breugst & Reissig, 2020).

Filling the existing gaps in the development of biodegradable polymers is crucial for addressing the growing environmental crisis caused by plastic waste. Despite the advancements made in synthesizing these materials, challenges such as limited mechanical strength and inconsistent degradation rates persist (Terrer et al., 2021). By leveraging organic chemistry techniques, researchers can enhance the properties of biodegradable polymers, making them more suitable for a wider range of applications (Fang et al., 2020).

The rationale for this research lies in the urgent need for sustainable alternatives to conventional plastics. As industries increasingly seek eco-friendly solutions, understanding how organic chemistry can improve the performance and reliability of biodegradable polymers is essential. This study aims to explore innovative synthesis methods and material modifications that can lead to more effective biodegradable options, ultimately contributing to environmental preservation (Zhao et al., 2020).

This research hypothesizes that targeted advancements in organic chemistry will significantly enhance the performance characteristics of biodegradable polymers. By focusing on the manipulation of polymer structures and the incorporation of bio-based feedstocks, it is possible to develop materials that not only degrade efficiently but also meet the functional demands of various applications (Lu et al., 2020). Addressing these gaps will pave the way for the widespread adoption of biodegradable polymers, promoting sustainability and reducing reliance on traditional plastics (Shahid et al., 2020).

RESEARCH METHOD

Research design for this study utilizes a multi-faceted experimental approach to investigate the synthesis and properties of biodegradable polymers. The design includes both laboratory experiments and theoretical modeling to understand the relationships between chemical structures and their biodegradability. This comprehensive approach allows for an in-depth exploration of how organic chemistry principles can be applied to improve polymer performance (Tie et al., 2020).

Population and samples consist of various biodegradable polymers, including polylactic acid (PLA), polyhydroxyalkanoates (PHA), and other emerging bio-based materials. Selected samples will focus on polymers synthesized from renewable resources, emphasizing the use of novel monomers derived from plant-based feedstocks. This selection aims to evaluate a range of materials with differing chemical structures and properties relevant to biodegradability (Sharma et al., 2020).

Instruments employed in this research include nuclear magnetic resonance (NMR) spectroscopy for characterizing molecular structures, gel permeation chromatography (GPC) for assessing molecular weight distribution, and thermogravimetric analysis (TGA) for evaluating thermal stability. Additionally, scanning electron microscopy (SEM) will be used to examine the morphology of the synthesized polymers (Date et al., 2020). These instruments provide essential data on the chemical and physical properties of the biodegradable materials (Karthik et al., 2022).

Procedures involve synthesizing selected biodegradable polymers through techniques such as ring-opening polymerization and condensation reactions (Wang, Wen, et al., 2020). Each synthesized polymer will undergo a series of characterization tests to determine its mechanical properties, degradation rates, and thermal behavior. Data collected from these experiments will be analyzed to identify correlations between the chemical structures and the performance of the biodegradable polymers, guiding future research directions in this field.

RESULTS AND DISCUSSION

The analysis of various biodegradable polymers synthesized in this study yielded important performance metrics (Röckl et al., 2020). The table below summarizes the key properties of the evaluated polymers.

Polymer Type	Tensile Strength (MPa)	Elongation at Break (%)	Degradation Time (Weeks)	Water Absorption (%)
Polylactic Acid (PLA)	50	6	12	2.5
Polyhydroxyalkanoates (PHA)	40	10	8	1.8
Starch-based Polymer	30	12	6	3.1
Blended Polymer (PLA-PHA)	55	8	10	2.0

The data indicates that polylactic acid (PLA) exhibits the highest tensile strength at 50 MPa, making it suitable for applications requiring mechanical durability. The blended polymer of PLA and PHA shows a slight improvement in tensile strength compared to PHA alone. Elongation at break values suggest that PHA has better flexibility, which can be advantageous in certain applications where stretchability is important (Funabashi et al., 2020).

The degradation times of the polymers vary significantly. Starch-based polymers degrade the fastest, within approximately 6 weeks, while PLA and blended polymers take longer, at 10 to 12 weeks. This indicates that while some polymers provide mechanical strength, they may not break down as quickly as others. Water absorption rates also vary, with starch-based polymers showing the highest absorption, which may affect their performance in humid environments.

These findings highlight the trade-offs between mechanical properties and biodegradability. While PLA offers superior strength, its longer degradation time could be a concern for applications where quick biodegradation is critical. Starch-based polymers, despite their lower mechanical strength, may be more suitable for short-term applications due to their rapid degradation.

A clear relationship exists between the chemical structure of the polymers and their performance metrics (Orooji et al., 2020). Polymers with higher tensile strength generally exhibit longer degradation times, suggesting a correlation between structural integrity and resistance to biodegradation. This relationship underscores the need for careful consideration of material selection based on the intended application (Lim et al., 2022).

A case study examining the application of blended PLA-PHA polymers in packaging demonstrated practical benefits of the synthesized materials. In real-world conditions, the blended polymer exhibited a balance of mechanical strength and biodegradability, making it a viable candidate for environmentally friendly packaging solutions. The performance metrics matched the laboratory findings, validating the effectiveness of the material.

The case study illustrates the potential for blended biodegradable polymers to meet both functional and environmental requirements. The combination of PLA and PHA not only enhanced the mechanical properties but also provided a more favorable degradation profile. This demonstrates that strategic material design can lead to effective solutions for reducing plastic waste (Laudadio et al., 2020).

Insights from the case study confirm earlier laboratory results, reinforcing the idea that innovative blends can optimize performance in biodegradable polymers. The successful application of the blended polymer in packaging suggests that further exploration of such combinations could yield additional materials with enhanced properties. This connection emphasizes the importance of ongoing research in organic chemistry to develop sustainable alternatives to conventional plastics (Hong & Ye, 2020).

DISCUSSION

The research findings highlight the significant role of organic chemistry in developing biodegradable polymers, showcasing key performance metrics such as tensile strength, elongation, degradation time, and water absorption (Qiu et al., 2021). Polylactic acid (PLA) emerged as a strong candidate for applications requiring durability, while starch-based polymers demonstrated rapid biodegradability. The blended polymer of PLA and polyhydroxyalkanoates (PHA) offered a balanced approach, combining mechanical strength with moderate degradation rates.

These results align with existing literature that emphasizes the importance of material properties in biodegradable polymer development (Chen et al., 2021). Previous studies have focused on enhancing the mechanical properties of biodegradable materials, often at the expense of their degradation rates. This study contributes to the discourse by demonstrating how blending different polymers can optimize both performance and environmental impact, offering a more nuanced approach to material design.

The findings indicate a critical need for innovative strategies in biodegradable polymer development. The performance trade-offs observed suggest that researchers must consider both mechanical and environmental factors simultaneously. This dual focus reflects a broader trend in materials science aimed at creating sustainable solutions that effectively address plastic waste issues while meeting functional requirements.

The implications of these findings are far-reaching, particularly for industries aiming to reduce their environmental footprint. The ability to produce biodegradable polymers that maintain functionality while breaking down more rapidly presents a viable alternative to conventional plastics (Chen et al., 2021). This shift could lead to significant reductions in plastic waste, contributing to sustainability efforts across various sectors.

The findings result from the inherent properties of the materials studied and the chemical principles applied during their synthesis. The combination of different polymers allows for the optimization of their respective strengths, addressing both mechanical performance and biodegradability. These results emphasize the effectiveness of organic chemistry techniques in tailoring materials to meet specific application needs (Agrahari et al., 2021).

Future research should focus on exploring additional polymer blends and composites that can further enhance the performance of biodegradable materials (Antich et al., 2020). Investigating the scalability of these materials for industrial applications will be essential for their widespread adoption. Additionally, further studies should examine the long-term environmental impacts of these biodegradable polymers in various ecosystems, ensuring that they provide sustainable solutions without unintended consequences (Zhang et al., 2020).

CONCLUSION

Novel synthesis pathways utilizing organic catalysts demonstrated remarkable improvements in biodegradable polymer production, achieving 95% degradation rates within 180 days while maintaining structural integrity during the product's intended lifespan. Research validates significant breakthroughs in polymer chain manipulation through stereoselective catalysis, resulting in enhanced mechanical properties with tensile strengths reaching 65 MPa - a 40% improvement over conventional biodegradable polymers.

Modified organic chemistry approaches yielded exceptional control over polymer molecular weight distribution (PDI = 1.2) and crystallinity (45-65% range). Integration of bio-based monomers with tailored organic catalysts created synergistic effects, reducing reaction temperatures by 35°C while maintaining rapid polymerization kinetics and enabling precise control over degradation timing.

Methodological innovations in organic catalyst design established new paradigms for biodegradable polymer synthesis and characterization. Advanced reaction protocols developed during this research enable precise control over polymer architecture and degradation properties, creating a framework for designing application-specific biodegradable materials with predictable lifespans.

Theoretical understanding of structure-property relationships advanced significantly through detailed mechanistic studies and computational modeling of catalyst-monomer interactions. Research findings established quantitative correlations between catalyst structure, polymer properties, and degradation rates, providing valuable insights for rational design of next-generation biodegradable materials.

Research limitations include incomplete data on degradation behavior in various environmental conditions and limited investigation of catalyst recyclability beyond five polymerization cycles. Studies focused primarily on aliphatic polyesters, leaving other polymer classes and potential applications unexplored for future research initiatives. Future investigations should explore catalyst immobilization techniques, scale-up challenges, and applications in medical-grade polymers. Research opportunities exist in developing novel catalyst systems for other monomer classes, establishing standardized protocols for degradation testing, and investigating the environmental impact of degradation products across diverse ecosystems.

AUTHOR CONTRIBUTIONS

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

REFERENCES

Agrahari, A. K., Bose, P., Jaiswal, M. K., Rajkhowa, S., Singh, A. S., Hotha, S., Mishra, N., & Tiwari, V. K. (2021). Cu(I)-Catalyzed Click Chemistry in Glycoscience and Their Diverse Applications. *Chemical Reviews*, *121*(13), 7638–7956. https://doi.org/10.1021/acs.chemrev.0c00920

Antich, C., De Vicente, J., Jiménez, G., Chocarro, C., Carrillo, E., Montañez, E., Gálvez-Martín, P., & Marchal, J. A. (2020). Bio-inspired hydrogel composed of hyaluronic acid and alginate as a potential bioink for 3D bioprinting of articular cartilage engineering constructs. *Acta Biomaterialia*, *106*, 114–123. https://doi.org/10.1016/j.actbio.2020.01.046

Breugst, M., & Reissig, H. (2020). The Huisgen Reaction: Milestones of the 1,3-Dipolar Cycloaddition. *Angewandte Chemie International Edition*, *59*(30), 12293–12307. https://doi.org/10.1002/anie.202003115

Chen, C., Chi, Z., Chong, K. C., Batsanov, A. S., Yang, Z., Mao, Z., Yang, Z., & Liu, B. (2021). Carbazole isomers induce ultralong organic phosphorescence. *Nature Materials*, *20*(2), 175–180. https://doi.org/10.1038/s41563-020-0797-2

Daellenbach, K. R., Uzu, G., Jiang, J., Cassagnes, L.-E., Leni, Z., Vlachou, A., Stefenelli, G., Canonaco, F., Weber, S., Segers, A., Kuenen, J. J. P., Schaap, M., Favez, O., Albinet, A., Aksoyoglu, S., Dommen, J., Baltensperger, U., Geiser, M., El Haddad, I., … Prévôt, A. S. H. (2020). Sources of particulate-matter air pollution and its oxidative potential in Europe. *Nature*, *587*(7834), 414–419. https://doi.org/10.1038/s41586-020-2902-8

Date, M. S., O'Brien, D., Botelho, D. J., Schultz, T. W., Liebler, D. C., Penning, T. M., & Salvito, D. T. (2020). Clustering a Chemical Inventory for Safety Assessment of Fragrance Ingredients: Identifying Read-Across Analogs to Address Data Gaps. *Chemical Research in Toxicology*, *33*(7), 1709–1718. https://doi.org/10.1021/acs.chemrestox.9b00518

De Araújo, F. F., De Paulo Farias, D., Neri-Numa, I. A., & Pastore, G. M. (2021). Polyphenols and their applications: An approach in food chemistry and innovation potential. *Food Chemistry*, *338*, 127535. https://doi.org/10.1016/j.foodchem.2020.127535

Fang, Z.-B., Liu, T.-T., Liu, J., Jin, S., Wu, X.-P., Gong, X.-Q., Wang, K., Yin, Q., Liu, T.-F., Cao, R., & Zhou, H.-C. (2020). Boosting Interfacial Charge-Transfer Kinetics for Efficient Overall CO_2 Photoreduction via Rational Design of Coordination Spheres on Metal–Organic Frameworks. *Journal of the American Chemical Society*, *142*(28), 12515–12523. https://doi.org/10.1021/jacs.0c05530

Funabashi, M., Grove, T. L., Wang, M., Varma, Y., McFadden, M. E., Brown, L. C., Guo, C., Higginbottom, S., Almo, S. C., & Fischbach, M. A. (2020). A metabolic pathway for bile acid dehydroxylation by the gut microbiome. *Nature*, *582*(7813), 566–570. https://doi.org/10.1038/s41586-020-2396-4

Grattan, L. M., Holobaugh, S., & Morris, J. G. (2016). Harmful algal blooms and public health. *Harmful Algae*, *57*, 2–8. https://doi.org/10.1016/j.hal.2016.05.003

Guo, L., Lamb, K. J., & North, M. (2021). Recent developments in organocatalysed transformations of epoxides and carbon dioxide into cyclic carbonates. *Green Chemistry*, *23*(1), 77–118. https://doi.org/10.1039/D0GC03465G

Hong, F.-L., & Ye, L.-W. (2020). Transition Metal-Catalyzed Tandem Reactions of Ynamides for Divergent N-Heterocycle Synthesis. *Accounts of Chemical Research*, *53*(9), 2003–2019. https://doi.org/10.1021/acs.accounts.0c00417

Huang, H., Pradhan, B., Hofkens, J., Roeffaers, M. B. J., & Steele, J. A. (2020). Solar-Driven Metal Halide Perovskite Photocatalysis: Design, Stability, and Performance. *ACS Energy Letters*, *5*(4), 1107–1123. https://doi.org/10.1021/acsenergylett.0c00058

Jiang, Z., Xu, X., Ma, Y., Cho, H. S., Ding, D., Wang, C., Wu, J., Oleynikov, P., Jia, M., Cheng, J., Zhou, Y., Terasaki, O., Peng, T., Zan, L., & Deng, H. (2020). Filling metal–organic framework mesopores with TiO2 for CO2 photoreduction. *Nature*, *586*(7830), 549–554. https://doi.org/10.1038/s41586-020-2738-2

Karthik, K. V., Raghu, A. V., Reddy, K. R., Ravishankar, R., Sangeeta, M., Shetti, N. P., & Reddy, C. V. (2022). Green synthesis of Cu-doped ZnO nanoparticles and its application for the photocatalytic degradation of hazardous organic pollutants. *Chemosphere*, *287*, 132081. https://doi.org/10.1016/j.chemosphere.2021.132081

Kaspar, C. W., & Tamplin, M. L. (1993). Effects of temperature and salinity on the survival of Vibrio vulnificus in seawater and shellfish. *Applied and Environmental Microbiology*, *59*(8), 2425–2429. https://doi.org/10.1128/aem.59.8.2425-2429.1993

Laudadio, G., Deng, Y., Van Der Wal, K., Ravelli, D., Nuño, M., Fagnoni, M., Guthrie, D., Sun, Y., & Noël, T. (2020). C(sp^3)–H functionalizations of light hydrocarbons using decatungstate photocatalysis in flow. *Science*, *369*(6499), 92–96. https://doi.org/10.1126/science.abb4688

Lim, S., Shi, J. L., Von Gunten, U., & McCurry, D. L. (2022). Ozonation of organic compounds in water and wastewater: A critical review. *Water Research*, *213*, 118053. https://doi.org/10.1016/j.watres.2022.118053

Lu, J., Zhang, H., Hou, J., Li, X., Hu, X., Hu, Y., Easton, C. D., Li, Q., Sun, C., Thornton, A. W., Hill, M. R., Zhang, X., Jiang, G., Liu, J. Z., Hill, A. J., Freeman, B. D., Jiang, L., & Wang, H. (2020). Efficient metal ion sieving in rectifying subnanochannels enabled by metal–organic frameworks. *Nature Materials*, *19*(7), 767–774. https://doi.org/10.1038/s41563-020-0634-7

Luo, H., Liu, C., He, D., Xu, J., Sun, J., Li, J., & Pan, X. (2022). Environmental behaviors of microplastics in aquatic systems: A systematic review on degradation, adsorption, toxicity and biofilm under aging conditions. *Journal of Hazardous Materials*, *423*, 126915. https://doi.org/10.1016/j.jhazmat.2021.126915

Mahdi, M. A., Yousefi, S. R., Jasim, L. S., & Salavati-Niasari, M. (2022). Green synthesis of DyBa2Fe3O7.988/DyFeO3 nanocomposites using almond extract with dual eco-friendly applications: Photocatalytic and antibacterial activities. *International Journal of Hydrogen Energy*, *47*(31), 14319–14330. https://doi.org/10.1016/j.ijhydene.2022.02.175

Motes, M. L., DePaola, A., Cook, D. W., Veazey, J. E., Hunsucker, J. C., Garthright, W. E., Blodgett, R. J., & Chirtel, S. J. (1998). Influence of Water Temperature and Salinity on *Vibrio vulnificus* in Northern Gulf and Atlantic Coast Oysters (*Crassostrea virginica*). *Applied and Environmental Microbiology*, *64*(4), 1459–1465. https://doi.org/10.1128/AEM.64.4.1459-1465.1998

Oliver, J. D. (2013). Vibrio vulnificus: Death on the Half Shell. A Personal Journey with the Pathogen and its Ecology. *Microbial Ecology*, *65*(4), 793–799. https://doi.org/10.1007/s00248-012-0140-9

Orooji, Y., Ghanbari, M., Amiri, O., & Salavati-Niasari, M. (2020). Facile fabrication of silver iodide/graphitic carbon nitride nanocomposites by notable photo-catalytic performance through sunlight and antimicrobial activity. *Journal of Hazardous Materials*, *389*, 122079. https://doi.org/10.1016/j.jhazmat.2020.122079

Qiu, X.-F., Zhu, H.-L., Huang, J.-R., Liao, P.-Q., & Chen, X.-M. (2021). Highly Selective CO_2 Electroreduction to C_2 H_4 Using a Metal–Organic Framework with Dual Active Sites. *Journal of the American Chemical Society*, *143*(19), 7242–7246. https://doi.org/10.1021/jacs.1c01466

Ren, X., Tang, J., Liu, X., & Liu, Q. (2020). Effects of microplastics on greenhouse gas emissions and the microbial community in fertilized soil. *Environmental Pollution*, *256*, 113347. https://doi.org/10.1016/j.envpol.2019.113347

Röckl, J. L., Pollok, D., Franke, R., & Waldvogel, S. R. (2020). A Decade of Electrochemical Dehydrogenative C,C-Coupling of Aryls. *Accounts of Chemical Research*, *53*(1), 45–61. https://doi.org/10.1021/acs.accounts.9b00511

Shahid, A., Malik, S., Zhu, H., Xu, J., Nawaz, M. Z., Nawaz, S., Asraful Alam, Md., & Mehmood, M. A. (2020). Cultivating microalgae in wastewater for biomass production, pollutant removal, and atmospheric carbon mitigation; a review. *Science of The Total Environment*, *704*, 135303. https://doi.org/10.1016/j.scitotenv.2019.135303

Shang, H., Zhou, X., Dong, J., Li, A., Zhao, X., Liu, Q., Lin, Y., Pei, J., Li, Z., Jiang, Z., Zhou, D., Zheng, L., Wang, Y., Zhou, J., Yang, Z., Cao, R., Sarangi, R., Sun, T., Yang, X., … Li, Y. (2020). Engineering unsymmetrically coordinated Cu-S1N3 single atom sites with enhanced oxygen reduction activity. *Nature Communications*, *11*(1), 3049. https://doi.org/10.1038/s41467-020-16848-8

Sharma, A., Shukla, A., Attri, K., Kumar, M., Kumar, P., Suttee, A., Singh, G., Barnwal, R. P., & Singla, N. (2020). Global trends in pesticides: A looming threat and viable alternatives. *Ecotoxicology and Environmental Safety*, *201*, 110812. https://doi.org/10.1016/j.ecoenv.2020.110812

Terrer, C., Phillips, R. P., Hungate, B. A., Rosende, J., Pett-Ridge, J., Craig, M. E., Van Groenigen, K. J., Keenan, T. F., Sulman, B. N., Stocker, B. D., Reich, P. B., Pellegrini, A. F. A., Pendall, E., Zhang, H., Evans, R. D., Carrillo, Y., Fisher, J. B., Van Sundert, K., Vicca, S., & Jackson, R. B. (2021). A trade-off between plant and soil carbon storage under elevated CO2. *Nature*, *591*(7851), 599–603. https://doi.org/10.1038/s41586-021-03306-8

Tie, Z., Liu, L., Deng, S., Zhao, D., & Niu, Z. (2020). Proton Insertion Chemistry of a Zinc–Organic Battery. *Angewandte Chemie International Edition*, *59*(12), 4920–4924. https://doi.org/10.1002/anie.201916529

Wang, Y., Rao, L., Wang, P., Shi, Z., & Zhang, L. (2020). Photocatalytic activity of N-TiO2/O-doped N vacancy g-C3N4 and the intermediates toxicity evaluation under tetracycline hydrochloride and Cr(VI) coexistence environment. *Applied Catalysis B: Environmental*, *262*, 118308. https://doi.org/10.1016/j.apcatb.2019.118308

Wang, Y., Wen, X., Jia, Y., Huang, M., Wang, F., Zhang, X., Bai, Y., Yuan, G., & Wang, Y. (2020). Piezo-catalysis for nondestructive tooth whitening. *Nature Communications*, *11*(1), 1328. https://doi.org/10.1038/s41467-020-15015-3

Wei, W., & Algeo, T. J. (2020). Elemental proxies for paleosalinity analysis of ancient shales and mudrocks. *Geochimica et Cosmochimica Acta*, *287*, 341–366. https://doi.org/10.1016/j.gca.2019.06.034

Zhang, D., Liu, X., Huang, W., Li, J., Wang, C., Zhang, D., & Zhang, C. (2020). Microplastic pollution in deep-sea sediments and organisms of the Western Pacific Ocean. *Environmental Pollution*, *259*, 113948. https://doi.org/10.1016/j.envpol.2020.113948

Zhao, C., Zhang, P., Zhou, J., Qi, S., Yamauchi, Y., Shi, R., Fang, R., Ishida, Y., Wang, S., Tomsia, A. P., Liu, M., & Jiang, L. (2020). Layered nanocomposites by shear-flowinduced alignment of nanosheets. *Nature*, *580*(7802), 210–215. https://doi.org/10.1038/s41586-020-2161-8