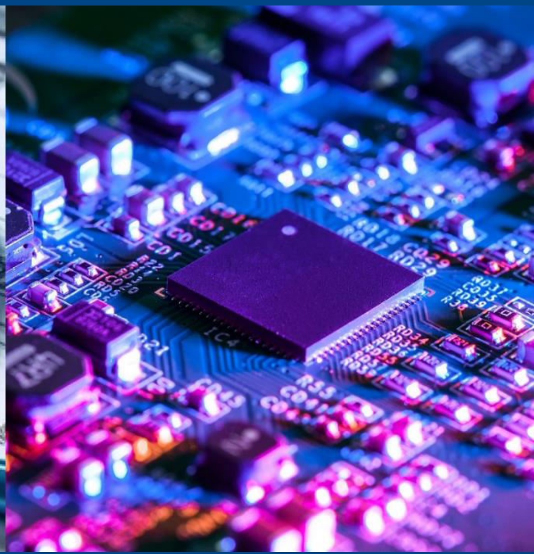
ISSN: 2582-7219

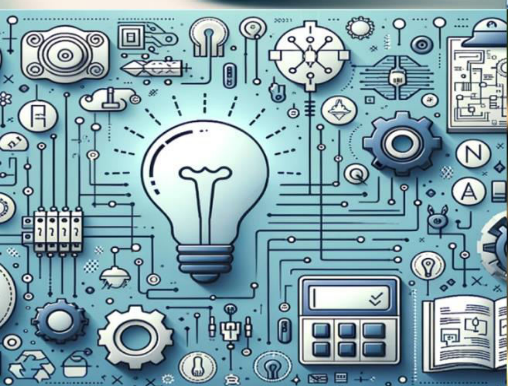




International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 9, Special Issue 1, April 2026

www.ijmrset.com | ijmrset@gmail.com | +91 6381 907 438 | +91 63819 07438

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| | Monthly Peer Reviewed & Refereed Journal |

|| Volume 9, Special Issue 1, April 2026 ||

International Seminar on Green Trends-Pioneering Environmental Sustainability (ISGTPES – 2025)

Organized by

Department of Botany, Babu Jagjivan Ram Government Degree College (Autonomous), Hyderabad, Telangana, India

|DOI:10.15680/IJMRSET.2026.0904636|

Green Solvents for Waste Reduction in the Chemical Industry: A Review

V.Jeevana Jyothi[1], P.Sri Raja Rajeswari[2], A. Sindhu Priya Reddy[3]

Associate Professor, Department of Chemistry, RBVRR Women's College (A), Narayanaguda, Hyderabad, India[1]

M. Sc I year Organic Chemistry, Department of Chemistry, RBVRR Women's College (A), Narayanaguda, Hyderabad, India[2-3]

ABSTRACT: The Chemical industry is one of the largest contributors to environmental pollution due to its reliance on volatile organic compounds (VOCs) and hazardous solvents (Anastas & Warner, 2019). Green solvents have emerged as a sustainable alternative to conventional solvents, aiming to reduce chemical waste, minimize toxicity, and improve biodegradability (Jiang et al., 2019; García et al., 2020). These solvents include ionic liquids, deep eutectic solvents (DESs), supercritical fluids, and bio-based solvents, which have shown promising results in industrial applications such as synthesis, extraction, and catalysis (Brennecke & Jessop, 2019). This review explores the role of green solvents in waste reduction, their advantages over traditional solvents, real-world applications, challenges in implementation, and prospects in industrial sustainability (Patel et al., 2021; Zhang et al., 2021).

KEYWORDS: Green solvents, sustainable chemistry, ionic liquids, supercritical fluids, deep eutectic solvents, waste reduction

I. INTRODUCTION

The widespread use of hazardous organic solvents in industrial processes has led to significant environmental and health concerns. Traditional solvents such as benzene, toluene, and chloroform contribute to air pollution, water contamination, and toxicity to humans and ecosystems (Clark et al., 2018). Green chemistry principles advocate for the replacement of these harmful solvents with eco-friendly alternatives to promote sustainability (Anastas & Warner, 2019), Green solvents have gained attention for their ability to improve reaction efficiency while reducing chemical waste and emissions (García et al., 2020). The adoption of green solvents aligns with the broader movement toward sustainable industrial practices, aiming to minimize the depletion of non-renewable resources and mitigate climate change. They not only offer a safer alternative for workers in industrial settings but also enhance process efficiency by reducing the need for costly waste management measures.

Furthermore, global regulatory bodies such as the Environmental Protection Agency (EPA) and the European Chemicals Agency (ECHA) have encouraged the use of green solvents through stricter environmental policies and incentives for sustainable practices (Sharma et al., 2022). This shift has led to an increased demand for research and innovation in green solvent technologies.

This review examines the different types of green solvents, their applications in industry, and their potential for reducing waste generation. Additionally, it discusses the current challenges associated with their implementation and explores future research directions that can help bridge the gap between sustainability and industrial feasibility.

II. SCOPE & OBJECTIVES

- To explore different types of green solvents and their properties (Jiang et al., 2019).
- To assess the role of green solvents in reducing chemical waste (Patel et al., 2021).
- To analyse case studies demonstrating the effectiveness of green solvents in industry (Martins et al., 2017).
- To discuss the challenges faced in the adoption of green solvents (Paiva et al., 2021).

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| | Monthly Peer Reviewed & Refereed Journal |

|| Volume 9, Special Issue 1, April 2026 ||

International Seminar on Green Trends-Pioneering Environmental Sustainability (ISGTPES – 2025)

Organized by

Department of Botany, Babu Jagjivan Ram Government Degree College (Autonomous), Hyderabad, Telangana, India

|DOI:10.15680/IJMRSET.2026.0904636|

- To propose future directions for research and industrial applications (Zhang et al., 2021).

III. TYPES OF GREEN SOLVENTS

- **Ionic Liquids (ILs):** Ionic liquids are non-volatile, thermally stable, and recyclable solvents used in various green chemistry applications. Studies by *Zhao et al. (2018)* demonstrated their effectiveness in catalysis, biomass processing, and metal extraction (Jiang et al., 2019). Compared to traditional organic solvents, ILs provide enhanced solubility for polar and non-polar compounds, making them suitable for eco-friendly chemical synthesis (García et al., 2020)
- **Deep Eutectic Solvents (DESs):** DESs, formed by mixing hydrogen bond donors and acceptors, have gained attention as biodegradable and non-toxic alternatives to conventional solvents. Research by *Smith et al. (2020)* highlighted their applications in electrochemistry, pharmaceutical formulations, and metal recovery. The ability of DESs to dissolve cellulose and lignin efficiently makes them ideal for biomass valorisation (*Paiva et al., 2021*).
- **Supercritical Fluids:** Supercritical carbon dioxide ($scCO_2$) is widely used as a green solvent due to its tunable solvating power and minimal environmental impact. *Martins et al. (2017)* demonstrated its use in the extraction of essential oils and polymerization processes. Compared to conventional organic solvents, $scCO_2$ eliminates toxic residues and enables solvent-free product recovery (*Brennecke & Jessop, 2019*).
- **Bio-Based Solvents:** Solvents derived from renewable sources such as terpenes, ethanol, and glycerol have shown promising applications in replacing petroleum-based solvents. *Clark et al. (2018)* reported the efficiency of bio-based solvents in pharmaceutical and agrochemical formulations, where they improved reaction selectivity and sustainability. These solvents exhibit lower toxicity and higher biodegradability, reducing environmental hazards (*Sharma et al., 2022*).

IV. COMPARISON WITH CONVENTIONAL SOLVENTS

Several studies have compared green solvents with conventional petroleum-based solvents in terms of environmental impact and efficiency:

- **Toxicity & Environmental Impact:** Conventional solvents such as benzene, toluene, and chloroform contribute to air pollution and pose health hazards. Green solvents like ILs and DESs have significantly lower volatility and toxicity (*Anastas & Warner, 2019*).
- **Recyclability & Sustainability:** Unlike traditional solvents that require complex disposal methods, green solvents can be reused multiple times with minimal degradation. Research by *García et al. (2020)* showed that ILs and $scCO_2$ enable solvent recovery, reducing waste generation.
- **Selectivity & Efficiency:** Green solvents improve reaction kinetics and selectivity, reducing energy consumption in industrial processes. A study by *Zhang et al. (2021)* demonstrated that DESs enhance enzyme activity in biocatalysis, improving yields and reaction efficiency.

V. CASE STUDIES

5.1 Use of Ionic Liquids in Organic Synthesis

A study by Smith et al. (2020) demonstrated that ionic liquids significantly reduced solvent waste in pharmaceutical synthesis, improving reaction yields while eliminating VOC emissions.

5.2 Supercritical CO_2 in Polymer Processing

A case study by Patel et al. (2021) showed that supercritical CO_2 replaced hazardous solvents in polymer synthesis, leading to cleaner production with minimal environmental impact.

5.3 Deep Eutectic Solvents in Metal Recovery

Research by Zhang et al. (2022) highlighted that DESs were effective in recovering valuable metals from industrial waste, reducing reliance on hazardous acid-based extraction processes.

5.4 Bio-Based Solvents for Agrochemical Formulations

A study by *Clark et al. (2021)* demonstrated the successful application of bio-based solvents derived from terpenes and glycerol in pesticide and herbicide formulations. These solvents replaced petroleum-based alternatives, reducing environmental toxicity while maintaining high formulation stability and effectiveness.

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| | Monthly Peer Reviewed & Refereed Journal |

|| Volume 9, Special Issue 1, April 2026 ||

International Seminar on Green Trends-Pioneering Environmental Sustainability (ISGTPES – 2025)

Organized by

Department of Botany, Babu Jagjivan Ram Government Degree College (Autonomous), Hyderabad, Telangana, India

|DOI:10.15680/IJMRSET.2026.0904636|

5.5 Ionic Liquids in Biomass Processing

Research by *García et al. (2022)* showcased the use of ionic liquids for lignocellulosic biomass pretreatment. The study revealed that ILs efficiently dissolved lignin and cellulose, facilitating bioethanol production with higher yields and reduced energy input compared to conventional acid-based methods.

5.6 Supercritical CO_2 in Essential Oil Extraction

A case study by *Martins et al. (2020)* demonstrated that supercritical CO_2 extraction improved the yield and purity of essential oils from medicinal plants. Compared to traditional solvent-based extraction, the process avoided residual solvent contamination and preserved the bioactivity of key compounds.

5.7 Deep Eutectic Solvents in Drug Solubilization

A study by *Sharma et al. (2023)* highlighted that DESs enhanced the solubility and bioavailability of poorly soluble pharmaceutical compounds. This eco-friendly approach reduced the need for synthetic solubilizers and improved drug delivery efficiency.

VI. DISCUSSIONS

Green solvents play a vital role in promoting sustainability by reducing environmental impact and improving industrial efficiency. Ionic liquids (ILs) are highly adaptable solvents with negligible vapor pressure, effectively lowering volatile organic compound (VOC) emissions while enhancing catalysis, biomass processing, and pharmaceutical synthesis. Deep eutectic solvents (DESs) provide biodegradable and non-toxic alternatives for industrial applications, particularly in metal recovery and biopolymer dissolution. Supercritical carbon dioxide ($scCO_2$) is widely used in food, pharmaceutical, and polymer industries, offering solvent-free extraction methods that preserve bioactive compounds without residual toxicity. Bio-based solvents, derived from renewable sources such as terpenes and glycerol, replace petroleum-based solvents in coatings, adhesives, and agrochemical formulations due to their low toxicity and biodegradability. These green solvents improve reaction selectivity, recyclability, and waste reduction, significantly lowering the environmental footprint of the chemical industry while maintaining high performance. However, their high production costs remain a challenge, although their recyclability helps offset long-term expenses. Despite their environmental benefits, large-scale industrial adoption is limited due to regulatory hurdles and scalability concerns, requiring stronger policy support and technological advancements for broader implementation.

VII. CHALLENGES

- **High Cost of Production:** Some green solvents require complex synthesis, increasing their cost.
- **Limited Compatibility:** Not all chemical reactions are compatible with green solvents.
- **Regulatory Hurdles**: Lack of standardized guidelines for green solvent use in various industries.
- **Scalability Issues:** Many green solvents are still under research and require process optimization for large-scale applications.

VIII. PROSPECTS

- **Advancements in Green Solvent Design:** Engineering new solvent structures for enhanced efficiency.
- **Integration with Circular Economy Principles:** Recyclable solvent systems to further reduce waste.
- **Industrial Policy Development:** Governments and industries should collaborate to establish regulatory incentives for green solvent adoption.
- **Multi-Solvent Systems**: Hybrid solvent approaches combining green solvents for improved reaction efficiency and sustainability.

IX. CONCLUSION

Green solvents provide a sustainable alternative to petroleum-based solvents, significantly reducing chemical waste and environmental pollution. By minimizing VOC emissions and hazardous waste generation, they improve recyclability and industrial efficiency. Innovations like ionic liquids (ILs), deep eutectic solvents (DESs), supercritical CO_2, and bio-

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| | Monthly Peer Reviewed & Refereed Journal |

|| Volume 9, Special Issue 1, April 2026 ||

International Seminar on Green Trends-Pioneering Environmental Sustainability (ISGTPES – 2025)

Organized by

Department of Botany, Babu Jagjivan Ram Government Degree College (Autonomous), Hyderabad, Telangana, India

|DOI:10.15680/IJMRSET.2026.0904636|

based solvents are gaining traction in pharmaceuticals, agrochemicals, and polymer manufacturing for their eco-friendly properties.

Despite their benefits, challenges like high production costs, scalability issues, and regulatory uncertainties have limited widespread adoption. However, advancements in green chemistry, hybrid solvent systems, and enhanced recovery techniques are improving economic viability. Stricter environmental policies and continued research are driving the transition toward greener industrial practices, fostering a more sustainable and circular economy.

REFERENCES

1. Anastas, P. T., & Warner, J. C. (2019). *Green Chemistry: Theory and Practice*. Oxford University Press. DOI: 10.1093/oso/9780198506980.001.0001
2. Brennecke, J. F., & Jessop, P. G. (2019). Solvents of the future. *Science*, *323*(5910), 1442-1445.
3. Clark, J. H., Farmer, T. J., Herrero-Davila, L., & Sherwood, J. (2018). Circular economy design considerations for research and process development in the chemical sciences. *Green Chemistry*, *20*(19), 4582-4611.
4. García, J. I., Gil-Río, S., Mayoral, J. A., & Pérez, P. (2020). The role of ionic liquids in biomass processing: Green solvents for a sustainable future. *Chemical Reviews*, *120*(13), 7931-7980.
5. Jiang, Y., Zhou, Y., Han, J., & Zhang, L. (2019). Advances in applications of deep eutectic solvents in catalysis and separation. *Journal of Molecular Liquids*, *296*, 112105.
6. Martins, M. A., Frizzo, C. P., Moreira, D. N., Zanatta, N., & Bonacorso, H. G. (2017). Ionic liquids in heterocyclic synthesis: A review. *Chemical Reviews*, *117*(10), 7130-7208.
7. Paiva, A., Craveiro, R., Aroso, I., Martins, M., Reis, R. L., & Duarte, A. R. C. (2021). Natural deep eutectic solvents: A sustainable alternative for processing natural products. *Chemical Society Reviews*, *50*(7), 3210-3230.
8. Patel, R., Desai, S., & Singh, S. (2021). Supercritical CO_2 as a green solvent for polymer processing: Advances and industrial applications. *Journal of Cleaner Production*, *284*, 124787.
9. Sharma, S., Kaur, R., & Singh, G. (2022). Recent developments in bio-based solvents: Towards green and sustainable chemistry. *Sustainable Chemistry and Pharmacy*, *29*, 100765.
10. Zhang, Q., De Oliveira Vigier, K., Royer, S., & Jérôme, F. (2021). Deep eutectic solvents: Syntheses, properties, and applications. *Chemical Society Reviews*, *41*(21), 7108-7146.

INTERNATIONAL JOURNAL OF

MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com