iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: X Month of publication: October 2025

DOI: https://doi.org/10.22214/ijraset.2025.74664

Green Chemistry

Sanket Katkar[1], Aryan Gonjari[2], Ajinkya Lokhande[3]
Mandesh Institute Of Pharmaceutical Science And Research Center Mhaswad, India

Abstract: Green Chemistry is the design of chemical processes and products which reduce or exclude the use and generation of poisonous, toxic, dangerous andbio-accumulative chemical substances. It's a new approach to scientifically grounded environmental protection and plays a vital part in controlling global warming, acid rain and climate change. Its principle plays an abecedarian tool in pollution forestallment, adding effectiveness, selectivity and minimizing waste product.
Keywords: Green Chemistry, Hazardous Substances, Waste product, Environmental protection.

I. INTRODUCTION

Green Chemistry is apre-science approach to design of chemical processes and products that reduce or exclude the anthropogenic use and generation of dangerous, poisonous andbio-accumulative chemical substances.
It means designing the material in the chemicals that will be used in the future and are better for mortal health and our terrain.
It helps scientists and experimenters to design an effective earth where mortal beings utilize everything through bio-geo-chemical cycle, so that every mortal life will be better and will achieve sustainable development.
Green chemistry is different from environmental chemistry because environmental chemistry identifies source, elucidates medium and quantifies problems in the earth terrain while green chemistry seeks these environmental problems by creating indispensable and safe technology.

A. Green Chemistry History

Sustainable chemistry came visible as a response to the adding environmental issues in the late 20th century. Notable mileposts include
1962- Silent Spring by Rachel Carson brought to light the pitfalls of chemical pollution(Carson, 1962).
1970s- The U.S. Clean Air Act and Clean Water Act environmental regulations were legislated(EPA, 1970).
1990s- The term green chemistry was officially chased by the U.S. Environmental Protection Agency(EPA) and exploration programs were initiated(EPA, 1991).
1998- Paul Anastas and John Warner described the 12 Principles of Green Chemistry, which have been the base of the discipline(Anastas and Warner, 1998).
As part of a unique action operated by the US Environmental Protection Agency(EPA) to encourage sustainable growth in chemical technology by business, academia, and government, Poul.T. Anastas constructed the term" green chemistry" in 1991. In 1995, the US presidential green chemistry challenge was launched. The working party on green chemistry was created by the International Union of Pure and Applied Chemistry in 1996. The first book and two magazines on the subject of green chemistry were published in 1990 by the Royal Society of Chemistry. In 1990, the royal society of chemistry published the first book and two diurnals on the content of green chemistry. Green chemistry is a new system for creating, recycling, and applying chemicals in order to lessen hazards to mortal health and the terrain, similar as
Clean chemistry
snippet frugality
Environmentally benign chemistry. 2- 8
Twelve principles of Green chemistry have been developed by Poul Anastas, speaks about the reduction of dangerous substances from the conflation, product and operation of chemical products. When designing a green chemistry process it's insolvable to meet the conditions of all twelve principles of the process at the same time, but it attempts to apply as numerous principles during certain stages of conflation.9-10

II. 12 PRINCIPLES OF GREEN CHEMISTRY

1) Prevention. It's better to help waste than to treat or clean up waste after it's formed.
2) snippet Frugality. Synthetic styles should be designed to maximize the objectification of all accoutrements used in the process into the final product.

3) lower Hazardous Chemical conflation. Whenever practicable, synthetic methodologies should be designed to use and induce substances that pose little or no toxin to mortal health and the terrain.
4) Designing Safer Chemicals. Chemical products should be designed to save efficiency while reducing toxins.
5) Safer Detergents and Auxiliaries. The use of supplementary substances(e.g. detergents, separation agents, etc.) should be made gratuitous whenever possible and, when used, inoffensive.
6) Design for Energy Efficiency. Energy conditions of chemical processes should be honored for their environmental and profitable impacts and should be minimized.However, synthetic styles should be conducted at ambient temperature and pressure, If possible.
7) Use of Renewable Feedstocks. A raw material or feedstock. should be renewable rather than depleting whenever technically and economically practicable.
8) Reduce derivations. gratuitous derivatization(use of blocking groups, protection/ deprotection, temporary revision of physical/ chemical processes) should be minimized or avoided if possible, because of similar ways. bear fresh reagents and can induce waste.
9) Catalysis. Catalytic reagents(as picky as possible) are superior to stoichiometric reagents.
10) Design for declination. Chemical products should be designed so that at the end of their function they break down into inoffensive declination products and do n't persist in the terrain.
11) Real- Time Analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real- time, in-process monitoring and control prior to the confirmation of dangerous substances.
12) Innately Safer Chemistry for Accident Prevention. Substances and the form of a substance used in a chemical process should be chosen to minimize the eventuality for chemical accidents, including releases, explosions, and fires.

A. Example of Principles

PREVENT WASTE Avoid conflation of dangerous andbio-accumulative products like polythene, DDT, methyl mercury composites.

snippet ECONOMY Design processes to maximize objectification of accoutrements into final product.

LESS HAZARDOUS conflation Avoid poisonous composites like organomercurials and methyl isocyanate.

BENIGN Detergents illustration- Supercritical CO_2 as anon-toxic detergent.

DESIGN FOR declination illustration- Biodegradable polylactic acid(PLA).

B. Application

Textile and Tannery Industry oDesigning Safer Chemicals Production Waste minimization in medicine discovery oDesigning Safer Chemicals Production oPolymer assiduity oFood and Industry

Green Technologies in the Pharmaceutical Industry Green Chemistry in Agrochemicals Waste minimization in medicine discovery Industrial Application of green chemistry Green Chemistry is n't a lab- curiosity; rather it aims at a big ideal of creating a sustainable hereafter. Adding a number of green methodologies developed by academic and artificial experimenters enables companies to manipulate these ideas. Assiduity, from small businesses to large pots, has formerly made strategic moves towards sustainability by espousing the principles of green chemistry. The development of lower dangerous processes and marketable products, the shift from hamstrung chemical routes towardsbio-based conflationand the relief of oil painting- grounded feed stocks by renewable starting accoutrements are only a many exemplifications of the major opinions taken that will eventually have vast consequences for the world chemical markets.Chemical manufacturers used green chemistry to reduce or exclude their use of TRI detergent and reagent chemicals. involves major chemicals, reagents, detergents, catalysts and nearly all types of organic responses for conflation of active pharmaceutical substances. Thus, numerous chemicals and chemical processes involved are dangerous, poisonous and may show adverse goods on mortal health and terrain. Pharmaceutical companies can impact and ameliorate the environmental performance with exercising green chemistry. Green chemistry is being employed to develop revolutionary drug delivery styles that are more effective and less poisonous and could benefit cases. Green chemistry has grown from a small idea into a new approach to the scientifically grounded environmental protection. By using green chemistry procedures, we can minimize the waste of accoutrements, maintain the snippet frugality and help the use of dangerous chemicals. Experimenters and pharmaceutical companies need to be encouraged to consider the principles of green chemistry while designing the processes and choosing reagents. Now that sustainability is on everybody ‟ s top- of- mind, Green Chemistry is more important than ever

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com

C. Green Chemistry in Pharmaceuticals

Green Detergents- Supercritical CO_2, ionic liquids.
Catalysis- Biocatalysis enhances selectivity and reduces waste.
Energy- Saving- Microwave oven- supported, flow chemistry.
Renewable Feedstocks- turmoil- grounded lactic acid.
medicine Design-Low- toxin motes used in silico modeling.
Case Studies Ibuprofen process optimization, Taxol from factory cell culture, Aspirin greener conflation.

D. Green Chemistry enterprise in India

- January 1999- National Symposium on Green Chemistry was organized by the Department of Chemistry, University of Delhi.
- 2001- IUPAC International Symposium on Green Chemistry was organized by the Department of Chemistry, University of Delhi.
- November 2003- The first factory on Green Chemistry patronized by the Indo- US S&T Forum was organized.
- December, 2009- IGCW- 2009(Industrial Green Chemistry World) was held in Mumbai, India. Over 1000 stakeholders of Chemical diligence came together for the first time to explore the possibilities of industrializing Green Chemistry and Green Engineering Technologies.

E. Indian institutes and exploration groups conducting exploration in the field of Sustainable Chemistry

ICT, Mumbai- One of the many in the world to work on green chemistry, which principally uses natural catalysts(enzymes) to carry out a chemical response. Indian Agricultural Research Institute(IARI) and the Defense Research and Development Organization(DRDO)- Monitoring and junking of heavy essence and fungicides in husbandry and agro products Indian Institute of Chemical Technology(IICT) Hyderabad- Developed solid support reagents and catalyst useful for organic metamorphoses. The Indian Association for the Civilization of Science(IACS)- herbage synthetic styles by designing response protocols without involving organic detergents.

perpetration Problems

High launch- up costs, specialized constraints, spanning issues, and lack of mindfulness are crucial challenges. Developing countries also face fresh obstacles in espousing green practices in medicinals.

Regulatory Frameworks

EPA Green Chemistry Program(1991)
EU REACH Regulation(2007)
Indian CPCB Sustainable Pharma Practices(2019)

unborn Prospects

Nanotechnology in medicine delivery, AI optimization of conflation, biocatalyst expansion, indirect frugality models.

III. ADVANTAGES

Green Chemistry reduces waste products. In actuality, green chemistry is a fresh strategy for guarding both the terrain and mortal health. Conservation of energy and that consumption has a significant impact on the terrain has long been conceded. Solid- state microwave oven irradiation 31 is a fashion that, in discrepancy to how they've historically been carried out in liquid results, is being employed to speed up chemical responses. Microwave oven- supported processes without detergent 32- 34 allow for the use of open holders, which lowers the peril of high pressure and increases the possibility that similar responses may be gauged up. The feasibility of microwave oven backed detergent free conflation has been demonstrated by a number of real- world metamorphoses and the conflation of heterocyclic systems.31- 34

IV. DISADVANTAGES

Creating chemical products and procedures that lessen or do down with dangerous chemicals is the abecedarian task of green chemistry. This ideal is also the most grueling for green chemistry, and it's particularly reflected in the quantum of time, plutocracy, and information needed to complete it. For illustration, switching from an outdated, conventional product to a new," green" one is frequently delicate and precious, and there's presently no agreement on what constitutes a safe position of chemical or raw material input.35, 36 Lack of green chemistry will affect from the high perpetration costs and lack of information, since there will be no defined option for using chemical raw accoutrements or indispensable technologies for green processes. Also, there's a deficit of mortal capabilities. The future of green chemistry is ionic liquids. Despite the fact that their value in chemical conflation is inarguable. Ionic liquids do n't primarily look like green chemicals when the 12 criteria that characterise them are applied. Although it's generally known that ionic liquids have a low vapour pressure and are thus slightly unpredictable, this is only one of the numerous factors that contribute to a material being green. For example, liquids grounded on ions, fluoro- anion, and imidazole are predicted to be poisonous, but they can not dematerialize into the terrain. The issue is that the maturity of ionic liquids are water answerable and can fluently enter the biosphere through this route.36- 39

A. Inventions and Green Chemistry

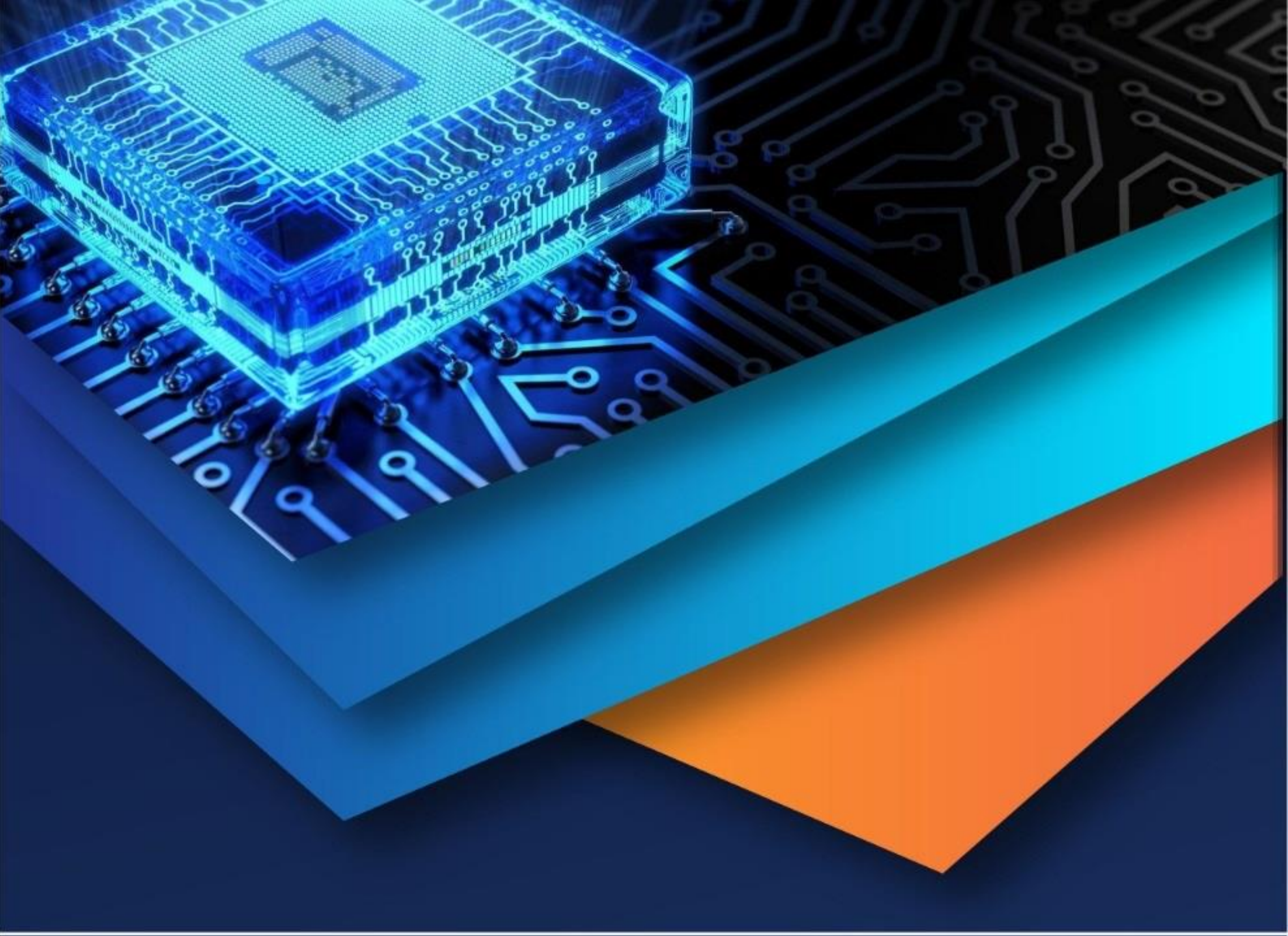
As we look across the field of Green Chemistry since its emergence as a cohesive field of study beginning with the development of environmentally friendly processes in the early 1990s, 1 it's possible to identify certain trends where important exploration has concentrated and where significant advances have been made. Clearly the area of environmentally benign detergents has been one of the leading exploration areas of Green Chemistry with great advances seen in waterless(biphase) catalysis 2,3 and the use of supercritical fluids in chemical responses. While the greenness of ionic liquids 5,6 and fluorous media7 will eventually depend on their individual parcels with respect to health and the terrain, the sustainability of new biobased solvents has to be proven as well. There has been a renewed focus on the age-old pursuit of the organic druggist to design and successfully apply the ideal conflation in terms of effectiveness, with atom9- 11 and step economy11 being a major thing. New catalytic processes continue to crop to advance the pretensions of Green Chemistry, while ways similar as microwave12- 14 and ultrasonic synthesis15 as well as in situ spectroscopic methods16- 17 have been used considerably, leading to spectacular results. These exploration areas are a regard to some of the numerous motifs directly applicable to Green Chemistry being pursued by experimenters around the world. With all of the exploration successes realized in Green Chemistry over the once 15 times, it's necessary to fete and understand that the field is in an incipient stage and that some of the most important exploration questions within it are only now beginning to be linked and pursued. As an exploration community, it's important to accelerate the pursuit of these exploration areas by easily enunciating the great exploration challenges, the great scientific unknowns within the field of Green Chemistry. Only through this exercise will the top institutions, the major backing agencies, and the primary artificial druggies of these inventions understand the power and eventuality of Green Chemistry exploration discoveries and be willing to give the support and backing demanded to see this field reach its eventuality. The current portfolio of feedstocks that are used moment as the base of the chemical enterprise is likely to be shifting, maybe dramatically over the coming decades, for reasons related to force, performance, economics, public pressures, and government- 27 The shift toward a further different feedstock base is an important future exploration area in Green Chemistry. While useful improvements have been made in demonstrating how to use biobased accoutrements similar as sugars and beans for introductory chemical structure blocks, it's an important consummation that if the scientific inventions are going to be suitable to be restated to the realm of profitable viability and societal benefit, these feedstocks will have to be penetrated in a way that does n't contend with land and agrarian coffers for food and feed product. This likely means that an important exploration challenge for Green Chemistry will be penetrating the biobased structure blocks through the application of agrarian waste products. This can only be met by totally exploiting the vast biofeedstocks which Nature courteously provides us, through broad- scale introductory exploration toward the development of effective, environmentally benign, and provident process methodologies for the large- scale conversion of biomass(carbohydrates, proteins, fats, terpenoids) into industrially feasible products, similar as bulk and intermediate chemicals, medicinals, and polymeric organic accoutrements. In this bid, public and supranational backing institutions will have to play an active part, not only by funding corresponding conditioning in a broad time frame(5- 10 times) but also by evolving a terse long- term strategy that takes root in academia and the chemical assiduity. The introductory strategy should be directed not only at the generation of the veritably same introductory chemicals that are well accessible from petrochemical sources but also toward the development of products with similar artificial operation biographies, with as little revision of the structural frame of the factors of the biomass as possible.

V. CONCLUSION

Herbage chemistry and operation of its 12 principles in the design of chemical processes and products help us achieve sustainable development with reduction in waste product and check environmental deterioration. It's a sustainable chemistry that makes our earth pollution-free from dangerous poisonous, dangerous substances.

REFERENCES

[1] Green Chemistry description/ American Chemical Society, www.acs.org.
[2] Anastas, P.T. Warner, J.C green chemistry; proposition and practice, Oxford University Press; New York, 1998.
[3] Fisher wisdom education, www.fisheredu.com.
[4] Environmental effect of war- Lenntech, www.lenntech.com.
[5] Abecedarian conception of Environmental chemistry, G.S. Sodhi.
[6] Fungicide chemistry and toxicology- Bentham eBooks.
[7] snippet frugality yields herbage assiduitywww.greens-industry.org.uk.
[8] Environmental Chemistry by A.K. DE.
[9] 2,4- D- Beyond fungicide, www.beyondpesticides.org.
[10] text of green chemistry Volume IV- herbage detergents, Paul T. Anastas.
[11] " The Nobel Prize in Chemistry 2005". The Nobel Foundation. recaptured2006-08-04.
[12] Noyori, R.(2005)." Pursuing practical fineness in chemical conflation". Chemical Dispatches(14) 1807 – 11. doi 10.1039/ B502713F. PMID 15795753.
[13] Baron, M.(2012)." Towards a Greener drugstore by further Eco Design"(PDF). Waste and Biomass Valorization. 3(4) 395 – 407. Bibcode2012WBioV.3.395B. doi 10.1007/ s12649-012-9146-2. S2CID 109584470.
[14] Jean- Pierre Schirmann, Paul Bourdauducq" Hydrazine" in Ullmann's Encyclopedia of Industrial Chemistry, Wiley- VCH, Weinheim, 2002. doi 10.1002/ 14356007.a13_177.
[15] Kurian, Joseph V(2005)." A New Polymer Platform for the Future – Sorona from Corn Derived 1,3- Propanediol". Journal of Polymers and the Environment. 13(2) 159 – 167. doi 10.1007/ s10924-005-2947-7. S2CID 137246045.
[16] "2011 Small Business Award". United States Environmental Protection Agency. 2013-03-12. Archived from the original on2014-11-29. recaptured2013-10-03.
[17] "Succinic acid maker BioAmber is bankrupt". Chemical & Engineering News. 2018-05-13.
[18] "Succinic acid, once a biobased chemical star, is barely being made". Chemical & Engineering News. 2019-03-20.
[19] Wilson, M. P.; Chia, D. A.; Ehlers, B. C. (2006). "Green chemistry in California: a framework for leadership in chemicals policy and innovation" (PDF). New Solutions. 16 (4): 365–372. doi:10.2190/9584-1330-1647-136p. PMID 17317635. SCID 43455643. Archived from the original (PDF) on 2010-06-11. Retrieved 2015-09-06.
[20] Wilson, M. P.; Schwarzman, M. R. (2009). "Toward a new U.S. Chemicals policy: Rebuilding the foundation to advance new science, green chemistry, and environmental health". Environmental Health Perspectives. 117 (8): 1202–9. Bibcode:2009EnvHP.117.1202W. doi:10.1289/ehp.0800404. PMC 2721862. PMID 19672398.
[21] "History of Green Chemistry | Center for Green Chemistry & Green Engineering at Yale". greenchemistry.yale.edu. Retrieved 2021-01-29.
[22] US EPA, OCSPP (2013-02-13). "Information About the Green Chemistry Challenge". US EPA. Retrieved 2021-01-29.
[23] California Department of Toxic Substances Control. "What is the Safer Consumer Products (SCP) Program?". Retrieved 5 September 2015.
[24] Matus, K. J. M.; Clark, W. C.; Anastas, P. T.; Zimmerman, J. B. (2012). "Barriers to the Implementation of Green Chemistry in the United States" (PDF). Environmental Science & Technology. 46 (20): 10892–10899. Bibcode:2012EnST...4610892M. doi:10.1021/es3021777. PMID 22963612.
[25] "Announcing the 2005 Canadian Green Chemistry Medal". RSC Publishing. Retrieved 2006-08-04.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY