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Professor Rajender S. Varma

A Tribute

**This commemorative issue of Arkivoc is dedicated to Dr. Rajender S. Varma
to acknowledge his remarkable career from the United States Environmental Protection Agency**

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It is with great pleasure that I introduce the issue of Arkivoc, dedicated to honouring the remarkable career of Dr. Rajender (Raj) S. Varma from the United States Environmental Protection Agency (US EPA).

Raj's journey in the realm of chemistry began in New Delhi, India, where his upbringing in various parts of the country cultivated a diverse perspective. He embarked on his academic pursuits, obtaining his B.Sc. from Punjab University in 1970 and M.Sc. in Chemistry from Kurukshetra University in 1972. It was under the mentorship of Prof. S. M. Mukherjee during his time at this university that his passion for chemistry was ignited. Pursuing further studies, Raj earned his Ph.D. in Organic (Natural Products) Chemistry from the University of Delhi in 1976, under the guidance of Professors T.R. Seshadri and M.R. Parthasarathy, delving into the exploration of secondary metabolites sourced from plants. His academic journey led him to diverse locales, including the Norwegian Institute of Technology in Trondheim, Norway (1977-78), where he honed his expertise in natural biopolymers, cellulose, and delignification processes. He was a senior research assistant in Robert Robinson Laboratories, University of Liverpool, United Kingdom (1979-1982) and a post-doctoral fellow at the University of Tennessee, Knoxville (1983-85). In 1985, Raj commenced his academic career at Baylor College of Medicine, Center of Biotechnology, Woodlands, Texas, with a concurrent senior scientist position at the neighbouring Technology Development Laboratory of the Houston Advanced Research Center (HARC), embarking on interdisciplinary research at the interface of chemistry and biology, solid state chemistry, and bioelectronics. He also held a research professorship (1996-1999) at Sam Houston State University, Huntsville, Texas prior to joining the US EPA's Sustainable Technology Division, National Risk Management Research Laboratory in Cincinnati, Ohio as a senior scientist. Currently, he is also an advisory board member of the Centre of Excellence for Research in Sustainable Chemistry, Department of Chemistry, Federal University of São Carlos, 13565-905 São Carlos – SP, Brazil.

His pioneering spirit led him to delve into the nascent field of green chemistry in the early nineties, exploring solvent-free reactions on mineral supports and the application of electromagnetic waves such as microwave and ultrasound to expedite chemical processes. His seminal contributions in this domain have laid the foundation for sustainable practices in chemical synthesis and have also catalyzed paradigm shifts in industrial practices worldwide. Notably, his groundbreaking research on alternative energy inputs, mainly microwave irradiation, has revolutionized chemical synthesis methodologies, finding widespread adoption in pharmaceutical drug discovery endeavors. His ventures in the solvent-free preparation of ionic liquids and their exploration as catalysts for utilization of carbon dioxide led to fruitful results in 2005. His single most impactful contribution in the Green Chemistry field has been in the area of alternative energy input into chemical reactions under a variety of eco-friendly conditions, most importantly utilizing microwave (MW) irradiation. He pioneered MW-assisted chemistry under solvent-free conditions in the early 1990's using a simple household microwave oven, at a time when dedicated MW equipment was just appearing. Raj has more than 125 peer-reviewed papers on this subject on his record, using benign solvents such as water and polyethylene glycol to assemble a wide variety of nitrogen and oxygen heterocyclic systems and eco-friendly chemical transformations. As a result, MW chemistry as an enabling technology has become a standard tool for pharmaceutical companiess in their drug discovery programs to generate libraries of 'lead' compounds.

In recent years, Raj's innovative pursuits have focused on biomimetic approaches to nanoparticle synthesis, epitomizing sustainable production practices. By leveraging natural resources and adopting environmentally benign synthesis routes, he has unlocked new frontiers in nanomaterial fabrication, with profound implications for catalysis and environmental remediation. His approach to mimic nature utilizes natural bio-renewable resources in nanoparticle synthesis, such as plant extracts and polyphenolic anti-oxidants from various sources, biodegradable polymers, such as cellulose, reducing sugars and agricultural residues (beet juice), waste material (red grape pomace) from winery waste, and glycerol (biodiesel by-product), avoiding the use of toxic agents, such as borohydrides, hydrazines or polyvinylpyrolidone, producing them in the matrix in which they are to be used thus reducing the risk of exposure or eliminating the use and generation of hazardous substances normally deployed. Of particular interest are nanoparticles with a magnetic core, a property that renders them recoverable for reuse. Beneficial consequences of these materials in the synthesis and greener remediation have been quite impressive on an international level, as evidenced by innumerable research projects and companies that have grown out of his research or used his technology. A quasi-homogeneous phase is provided via functionalization of the surfaces of nano-sized magnetic materials, acting as a bridge between heterogeneous and homogeneous catalysis thus retaining the relative advantages of both of the catalysis systems. The possibility of recycling using an external magnet is an asset. Magnetically separable materials not only recover and identify the dispersed nanomaterials in the environment, but C-, N- and S-doped TiO_2 exhibited a remarkable photodegradation activity, including for cyanobacterial toxins found in water (algal blooms). This research has lately been extended to 'doped' graphitic carbon nitrides that can be easily prepared

from urea. His commitment to sustainability extends beyond the laboratory, as evidenced by his efforts to inspire, and mentor the next generation of scientists worldwide, particularly in underprivileged communities.

Raj's scholarly impact is underscored by a prolific publication record comprising >985 peer-reviewed papers, 14 US patents, 11 books, and 31 book chapters, garnering over 76,800 citations. He presented more than 400 plenary and invited keynote lectures at international conferences and educational and research institutions all over the world. He has influenced a new generation of scientists especially regarding the development and application of Green Chemistry.

Raj is member of the editorial boards of a number of scientific publications such as ACS Sustainable Chemistry & Engineering (American Chemical Society), Green Chemistry (Royal Society Chemistry); International J. Green Nanotechnology (Taylor and Francis); Organic and Medicinal Chemistry Letters (Springer-Verlag, Heidelberg, Germany); Current Organic Chemistry, Current Green Chemistry, Current Organocatalysis, and Current Microwave Chemistry (Bentham Science), Green and Sustainable Pharmacy, Current Opinion in Green and Sustainable Chemistry (Elsevier), among others.

Because of his numerous esteemed accomplishments in research and impressive contributions to the community, US EPA has given him a number of awards which include an Office of Research and Development (ORD) Sustainability Award (2015), for "Sustainable Strategies for Risk Reduction In Nanotechnology: Application in Chemical Catalysis and Environmental Remediation", a Silver Medal for Superior Service-EPA for outstanding scientific and leadership contributions establishing EPA as a pioneering organization in the area of Green Chemistry (2013), several National Risk Management Research Laboratory Awards: A Systems Approach to Sustainable Solutions (2012), Environmental Solutions (2010), Visionary of the Year Award - Green Technology for the Environment (2009), numerous Science and Technology Achievement Awards on varied topics: Exceptional Technical Achievement in Developing a Microwave Technology for Greener Chemical Processing in Water; Designing a Process for Converting Greenhouse Gas, CO_2, to Cyclic Carbonates in Non-Volatile Ionic Liquid Solvents; Developing a Novel Approach for Greener Production and Safer Use of Noble Nanometals and Metal Oxides (2007), and Greener Strategies for Chemical Synthesis (2003). During prior years (1996-2002), Raj was also honored by international organizations for his outstanding lecturing commitments and research. These awards are Themis Medicare Chemcon Distinguished Speaker Award from Indian Institute of Chemical Engineers (I.I.Ch.E.), Prof. S. Ramaseshan Distinguished Lecture Award, Astrazeneca Research Foundation, Prof. R. A. Rajadhyaksha Distinguished Speaker Award, University Department of Science and Technology, University of Mumbai, Mumbai, India, and Marjorie W. Margolin Prize for outstanding contribution to Retina Research, The Retina Research Foundation, Houston, USA.

On a personal note, it is an honor to count Raj as both a friend and a colleague, whose unwavering passion for research continues to inspire us all. I extend my heartfelt gratitude to Raj's colleagues and friends worldwide for their contributions to this special issue, which reflects the breadth and depth of his scientific legacy. Through this tribute, we celebrate Raj's indelible imprint on the scientific community and his enduring commitment to advancing knowledge for the betterment of society.

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Selected Publications

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