Bio-Hydrogen: A Clean and Green Energy

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The excessive use of fossil fuels is one of the primary causes of global warming and acid rain, which have started to affect the earth's climate, weather, vegetation and aquatic ecosystems. Due to global environment and national energy security considerations, a non-polluting and renewable energy source needs to be developed.

Hydrogen is a promising energy carrier of the future. It can be derived from a variety of energy sources and used in fuel cells with high efficiency. The most common industrial methods for producing hydrogen include steam reformation of natural gas, coal gasification, and splitting water with electricity typically generated from fossil fuels. These energy-intensive industrial processes release carbon dioxide and other greenhouse gases and pollutants as by-products. Some microorganisms produce hydrogen naturally, and biotechnologies based on these microbial systems could lead to the development of clean, renewable sources of hydrogen. In a recent report on the hydrogen economy, however, the National Research Council (NRC) noted that "substantial, fundamental research needs to be undertaken before photobiological methods for large-scale hydrogen production are considered".

Biological hydrogen production is done in a bioreactor based on the production of hydrogen by algae. Under certain conditions, green algae and cyanobacteria can use water-splitting photosynthetic processes to generate molecular hydrogen (H_2) rather than fix carbon, the normal function of oxygenic photosynthesis. In this conceptual process, an initial photosynthetic stage, an open pond microalgae cultivation system, fixes CO_2 into starch (green algae) or glycogen (cyanobacteria). This is followed by a second stage, where the algae are concentrated as needed, become anaerobic (through respiration), induce the hydrogenase enzyme and start evolving H_2 from their stored carbohydrates in a dark fermentation. Finally, a light-driven H_2 production stage would complete the conversion of the biomass to H_2, using only part of the photosynthetic apparatus of the algae. A single organism, a green algae or a cyanobacterium, would carry out all these reactions, and be reused through several such cycles of CO_2 fixation and H_2 evolution (with CO_2 recycled between stages). In the absence of oxygen and presence of light, purple nonsulfur (PNS) photosynthetic bacteria such as *Rhodopseudomonas palustris* and *Rhodobacter sphaeroides* contain nitrogenase enzymes that can generate hydrogen under nitrogen-limited conditions. A variety of bacteria such as *E. coli*, *Enterobacter aerogenes*, and *Clostridium butyricum* are known to ferment sugars and produce hydrogen using multienzyme systems.

Photosynthetic microbes that have been genetically modified to produce hydrogen at high rates and efficiency from the biophotolysis of water could be grown in extensive farms of sealed enclosures (photobioreactors). Understanding biophotolysis well enough to model hydrogenase structure and function, regulatory and metabolic networks, and eventually entire organisms will stimulate the kind of biotechnological innovation needed to engineer the ideal organism to use in hydrogen bioreactors or the ideal enzyme-catalyst to use in bioinspired nanostructures for hydrogen production. But achieving this level of understanding will require basic research that investigates a greater range of hydrogen-producing enzymes and organisms, mechanisms of hydrogenase assembly, oxygen sensitivity of hydrogenase, electron-transfer rate limitations, and regulatory and metabolic processes that influence hydrogen production. Some specific issues relevant to this basic research needs to be addressed in order to produce bio-hydrogen.

Brief CV of Prof B V Babu

Dr B V Babu is Professor of Chemical Engineering and Dean of Educational Hardware Division (EHD) at Birla Institute of Technology and Science (BITS), Pilani. He did his PhD from IIT-Bombay. He is on various academic and administrative committees at BITS Pilani. He has 23 years of Teaching, Research, Consultancy, and Administrative experience. He currently has 4 research projects from UGC, DST, and KK Birla Academy. His research interests include Evolutionary Computation, Environmental Engineering, Biomass Gasification, Energy Integration, Artificial Neural Networks, Process Intensification, and Modeling & Simulation. He has around 165 research publications to his credit. He has published five books, and wrote several chapters in various books. He is Editorial Board Member of International Journals 'Energy Education Science & Technology', 'Research Journal of Chemistry and Environment' & 'International Journal of Computer, Mathematical Sciences and Applications', 'Journal on Future Engineering and Technology' and 'International Journal of Applied Evolutionary Compuration'. He is the referee & expert reviewer of 38 International Journals. He reviewed five books of McGraw Hill, Elsevier, John Wiley & Sons, Oxford University Press, and Tata McGraw Hill publishers.

He is the recipient of National Technology Day (11th May, 2003) Award of CSIR, obtained in recognition of the research work done in the area of 'A New Concept in Differential Evolution (DE) – Nested DE'. One of his papers earned the *Kuloor Memorial Award, 2006 awarded for the Best Technical Paper* published in the Institute's Journal "Indian Chemical Engineer" in its issues for 2005.

He is Life member of many professional bodies such as IIChE, ISTE, IE (I), IEA, SOM, Fellow of ICCE, Associate Member of ISSMO, IIIS, and IAENG. He completed three consultancy projects successfully. He was the Invited Chief Guest and delivered Keynote addresses at four international conferences and three national seminars. He organized many Seminars & Conferences at BITS-Pilani. He chaired many Technical Sessions at various International & National Conferences, and delivered innumerable invited talks at various IITs and Universities abroad.

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