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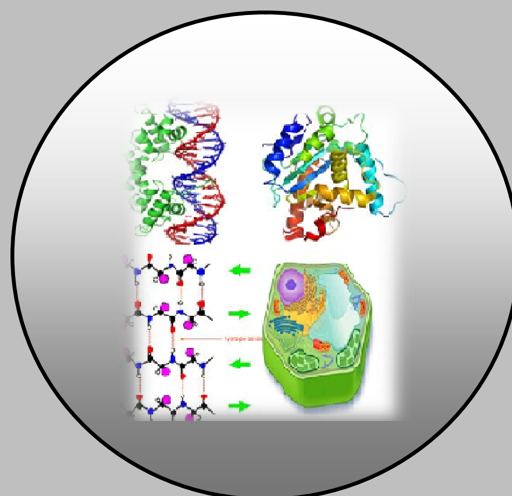

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REVIEW ARTICLE

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Green Chemistry towards Sustainability of Environmental Perspectives

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ABSTRACT

With the span of last two decades, a term 'Green Chemistry' has emerged with an aim to protect human health, and environment in an economically viable and sustainable stratagem. Green chemistry encompasses all type of chemical processes including synthesis, catalysis, analysis, monitoring, separation and reaction conditions that reduces the risk to human health and environment relative to current state-of-the-art. For a common man it can be explained as a refined form of chemistry where design of reactants, products and processes are utilized so as to reduce or eliminate the use or generation of hazardous substances. The term 'design' here focuses on conscious and deliberate use of a set of principles, methodologies and practices, which clearly means that green chemistry never gets accompanied by serendipity alone. Use of 'generation' implies the requirement of the life cycle consideration and sustainability. The term 'hazardous' in a broad context includes a wide range e.g., (viz. O_3 – depletion, GHE, glacial melt down, earth's radiation balance, climate change etc), toxicological (viz. Mutagenic, carcinogenic, teratogenic etc), and physical (viz. Inflammables, explosives, etc) hazards. Advances in chemistry address both obvious hazards and those associated with such global issues as climate change, energy production, safe potable and adequate water supply, and simple and healthy food resources. The designing of environmentally begin products and process is being guided by twelve principles, laid down by the founders of green chemistry – Paul T Anastas and John C Warner from the US. The environment is a common resource shared by the entire globe. The impact of cumulative changes brought about by human activities is increasingly becoming evident both in terms of development and more so in the form of deterioration of the environment.

Green chemistry is a welcome step towards protecting the mother earth from ecological imbalance and environmental degradation posed by resource exploitation, urbanization, industrialization and bad agricultural practices incurred due to excess human activities. The term 'Green Chemistry' has emerged with an aim to protect human health and the environment in an economically viable and sustainable manner. The designing of environmentally benign products is being guided by certain principles, laid down by the father of green chemistry- Paul T Anastas from the US. The environment is a common resource shared by the entire globe. Green chemistry is a welcome step towards protecting the environment. Green chemistry represents the pillars that hold up our sustainable future. It is imperative to teach the value of green chemistry to tomorrow's chemists. It is clear that many industries and research of many academics recognize the significance of green chemistry. This article delineates various applications & a brief description on perspectives green chemistry.
Keywords: Benign Solvents, Safer Chemicals, Sustainable Development, Twelve Principles, Biofuel, Green Plastic, GHGs and Environmental Degradability.

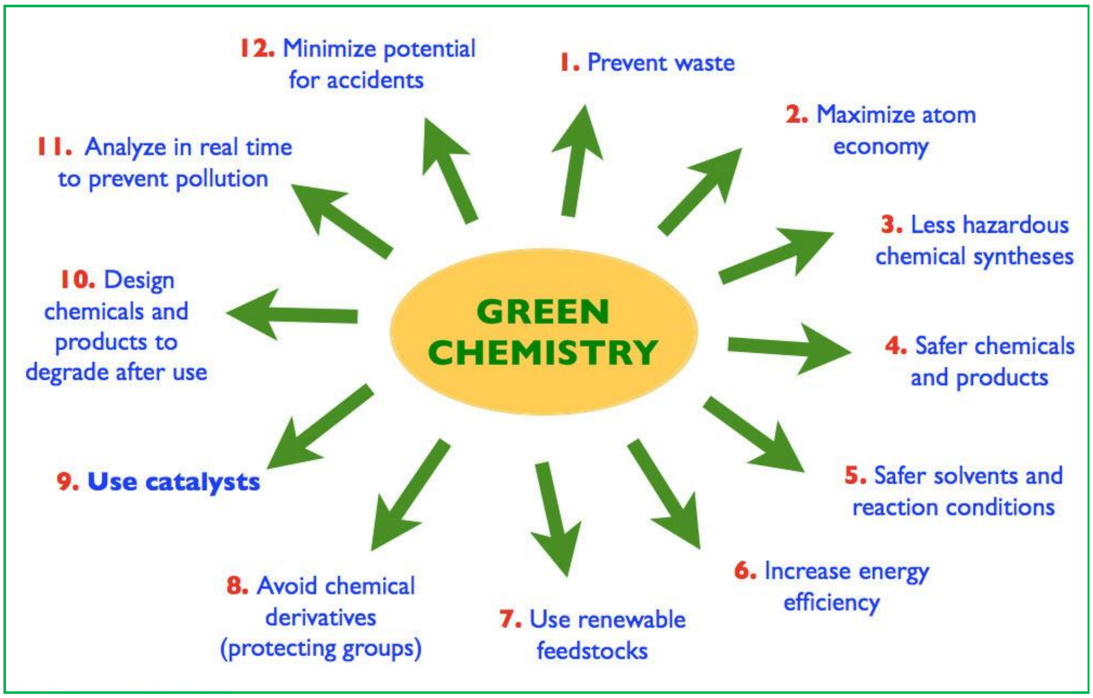
INTRODUCTION

Green chemistry revolution provides an enormous number of opportunities to discover and apply new synthetic approaches using alternatives Feedstock's; Ecofriendly reaction conditions, energy minimizations and the design of less toxic and inherently safer chemicals. The origin and basis of green chemistry for achieving environmental and economic prosperity is inherent in sustainable world. One important element of sustainable chemistry is commonly defined as the chemical research aiming at the optimization of chemical and products with respect to energy and material consumption, inherent safety, toxicity, environmental degradability, and so on. While considerable progress has made in environmental chemistry, green chemistry, and the environmental assessment of chemical products, however, the societal aspect of sustainable chemistry remains to be fully recognized in all branches of chemical research. One prerequisite for this is the inclusion of sustainable chemistry into chemical education from the very beginning. Green chemistry is not different from traditional chemistry in as much as it embraces the same creativity and innovation that has always been central to classical chemistry. However, there lies a difference in that historically synthetic chemists have not been seen to rank the environment consciousness throughout the world there is a change for chemists to develop new products, processes and services that achieve necessary social, economical and environmental objectives. A wave of concern for the environment swept across the developed countries in the 1960s and reached its climax in 1970 with the celebration of 'Earth Day' on March equinox (21 March 1970) under the auspices of the United Nations. The term green Chemistry was coined by chemist Paul Anastas (father of green chemistry) in 1991, of US – (Environmental Protection Agency) EPA. During 1992, United Nations Conference on Environment and Development (UNCED) was adopted in Rio de Janeiro. On US President Bill Clinton's initiative, EPA started to give a yearly award, "the US Presidential Green Chemistry Challenge Award".

Similar trends have been set in Great Britain, Australia, Italy, Germany and Japan. Joe Been established 'The Green Chemistry Institute' in United States. A number of manuscripts and books have been published on the subject. According to the work carried out by Paul T Anastas, the following principles of green chemistry have been formulated.

BASIC PRINCIPLES OF GREEN CHEMISTRY

Green chemistry is defined as environment benign chemical synthesis. Any synthesis, whether performed in teaching laboratories or industries should create none or minimum



by-products which pollute the atmosphere. According to the work carried out by Paul T Anastas, the following basic principles of green chemistry have been formulated[1].

- (Prevention of waste/ by-products) It is better to prevent waste than to clean up waste after it is formed.
- (Maximum incorporation of the reactants, starting materials and reagents, into the final product) Synthetic method should be designed to maximize the incorporation of all materials used in the generation process into the final product.
- (Prevention or minimization of hazardous products) Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
- (Designing of safer chemicals) Chemical products should be designed to preserve efficacy of function while reducing toxicity.
-

- (Energy requirement for any synthesis should be minimum) Energy requirement should be recognized for their environmental and economic impacts, and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
- (Selecting the most appropriate solvents). The use of solvents, separation agents, etc (auxiliary substances) should be made unnecessary whenever possible and innocuous when used.
- (Selecting the most appropriate starting materials) A raw material of feedstock should be renewable rather than depleting wherever technically and economically practicable.
- (Use of protecting group should be avoided whenever possible) Unnecessary preparation of derivatives, by blocking groups, temporary modification of physical/chemical processes etc, should be avoided wherever possible.
- (Use of catalysts should be preferred wherever possible) Catalytic reagents, as selective as possible, should be considered superior to stoichiometric reagents.
- (Products obtained should be biodegradable) Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.
- (The manufacturing plants should be so designed as to eliminate the possibility of accidents during operations) Substances and form a substance used in chemical processes should be chosen so as to minimize the potential for chemical accidents, including releases, explosions and fire.
- (Strengthening of analytical techniques to control hazardous compounds) Analytical methodologies need to be developed to allow for real time, in-process monitoring and control prior to the formation to hazardous **substances.**

GREEN CEMISTRY AT A GLANCE

Chemistry, sustainability and innovation—three key components are for the future of our society. Chemistry is an essential tool in our campaign to protect and preserve our environment, biodiversity and natural resources against further degradation. It is also a primary driver both for the growth and sustainable development of the world economy and the well-being and quality of life of its citizens. The challenges for the chemical sciences are the key to solve the challenges that society will face over the next years: energy, food, clean water, medicines and vaccines, protection of our environment and cultural heritage, and economic development. At present, protection of the environment is a huge concern for society. Problems including global warming and ozone depletion highlight the negative effects human activity has on the planet. Not only the environment is getting affected by human endeavors but this also has detrimental effects on human health. Sustainable chemistry is therefore not only concerned with the reduction of hazardous substances and waste and the environmental impact of the chemical industry;

It is part of a strategic long-term vision for the future of society, not disjoint from or antagonist to economic development but rather a key factor for innovation and competitiveness. In the current era there is a serious push towards developing processes that are eco-friendly. This necessitates a shift from the traditional concepts of the process efficiency that focuses exclusively on the chemical yield to one that assigns economic value to eliminating waste and avoiding the use of toxic and hazardous substances and focusing on more environmentally acceptable processes. To keep the green chemistry concern in mind, many industries are trying to synthesize target compounds by green chemistry routes. Chemistry has to and will play a major role to provide solutions for the crucial problems of the next century such as Energy; Use of Renewable Resources; Green Pharma and Health; and Elemental sustainability. Prompt global action to solve the energy crisis is needed. Such an action should be incorporated in a more general strategy based on the consciousness that the Earth's resources are limited. We are urged to save energy and to use energy in more efficient ways, and we are also forced to find alternative energy sources as soon as possible. The answer to the energy problem confronting this planet deals in the chemist's currency. As chemists, we can help by improving energy technologies and, hopefully, finding a scientific breakthrough capable of solving the energy problem at its root. The production of renewable chemicals is gaining attention over the past few years. The natural resources from which they can be derived in a sustainable way are most abundant in sugars, cellulose and hemicellulose. These highly functionalized molecules need to be de-functionalized in order to match the traditional feedstocks for the chemical industry. A fundamentally different approach to chemistry thus becomes necessary, since the traditionally employed oil-based chemicals normally lack functionality. This new chemical toolbox needs to be designed to guarantee the demands of future generations at a reasonable price. Many low carbon technologies including wind turbines, electric cars and catalytic converters require precious metals or other metals in unprecedented quantities threatening their continued availability. These elements are being dispersed in the form of waste throughout our environment, making them costly & difficult to recover. This emphasizes the necessity for a new approach to metal capture & use, thus increasing the lifetime of our reserves. The Pharmaceutical industry is the most dynamic part of the chemical industry. It is in the forefront for big changes towards "greener" feedstocks, safer solvents, alternative processes and innovative ideas. All these changes will increase the environmental credentials of the pharmaceutical industry, but at the same time will cut down cost and materials for the manufacturing operations making a step in the right direction of sustainability. Encouraging innovation, while integrating green chemistry and engineering into drug discovery, development and manufacturing of new pharmaceuticals is one of the most important issues in the health and pharmaceutical sector.

GREEN CHEMISTRY IN DAY TO DAY LIFE

With the advancement of science, green chemistry has changed our life style. Some of it important applications are described.

DRY CLEANING OF CLOTHES

Percholoroehylene (PERC) $Cl_2C{=}CCl_2$, commonly being used a solvent for dry cleaning. It is known that PERC contaminates groundwater and is a suspected human carcinogen.

A technology developed by Joseph De Simons, Timonthy Romack, and James Clain made use of liquid CO_2 and a surfactant for dry cleaning cloths, thereby replacing PERC. Dry cleaning machines have been developed using this technique. Micell technology has also evolved a metal-cleaning system that uses CO_2 and a surfactant, thereby eliminating the need of halogenated solvents[2].

VERSATILE BLEACHING AGENT

It is common knowledge that paper is manufactured from wood (which contains about 70% polyssacharides and about 30% lignin). For good quality paper, the lignin must be completely removed. Initially, lignin is removed by placing small chipped pieces of wood into a bath of NaOH and Na_2S (that is how pulp is formed). By this process about 80-90% of lignin is decomposed. The remaining lignin was so far removed through reaction with Cl_2 gas. The use of chlorine removes all the lignin (to give good quality white paper) but causes environmental problems. Chlorine also reacts with aromatic rings of the lignin (or aromatic substitution) to produce dioxins, such as 2, 3, 7, 8- tetrachlolo-p-dioxin and chlorinated furans. These compounds are potential carcinogen and cause other health problems. These halogenated products find their way into the food chain and finally into products like dairy products, pork, beef and fish. In view of this, use of chlorine has been discouraged. Subsequently, chlorine dioxide was used. Other bleaching agents like H_2O_2, O_3 or O_2 also did not give the desired results. A versatile bleaching agent has been developed by Terrence Collins of Carnegie Mellon University. It involves the use of H_2O_2 as a bleaching agents in the presence of some activators known as TAML activators[3] that act as catalyst which promote the conversion of H_2O into hydroxyl radicals that are involved in oxidation/bleaching. The catalytic activity of TAML allows H_2O_2 to breakdown more lignin in a shorter time and at much lower temperature, these bleaching agents also find use in laundry and result in lesser use of water[3].

GREEN PLASTIC ENGINEERED

It has been successfully bio-engineered polymers, completely bypassing fossil fuel based chemicals. This breakthrough opens the way for the production of 'green' plastics on commercial scale. The team from KAISTU, South Korea and LG Chem., led by Sang Yup Lee, focused on PLA (-a bio-based polymer considered a good alternative to petroleum based plastics as it's both biodegradable and less toxicity to humans), the key to producing plastics through renewable resources. Until now PLA has been generated in a two-step fermentation and polymerization, which is both complex and expensive. Now, through the use of a metabolically engineered strain of E coli, PLA and its co-polymers through fermentation have been produced, making the renewable production of PLA and lactate-containing copolymers cheaper and more commercially viable. By developing a strategy which combines metabolic engineering and enzyme engineering, an efficient bio-based one step production process for unnatural efficient PLA and its copolymers have been developed.

DON'T RECYCLE, UPCYCLE PLASTIC

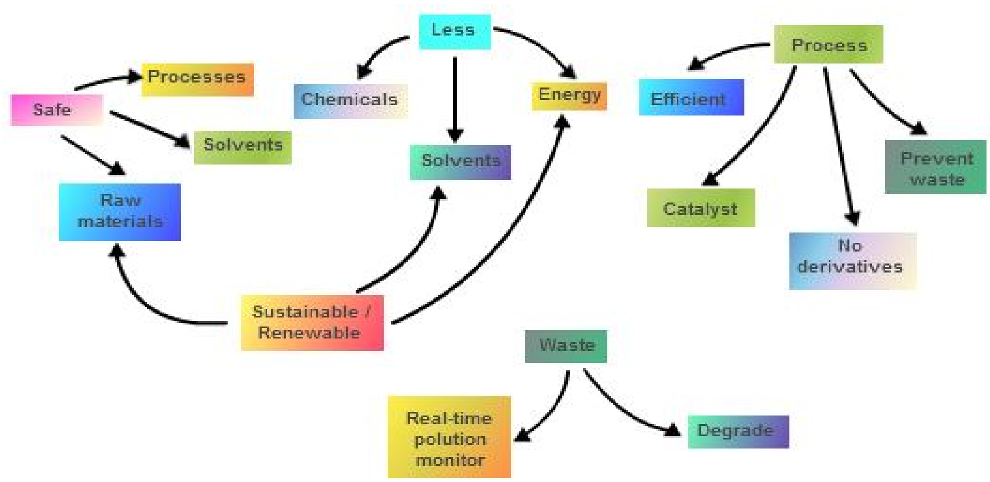
A marvel of modernity, plastic has become an indispensible part of our daily lives. But repeated reprocessing disposal of plastic waste is environmentally unfriendly, polluting and a potential health risk. A new method proposes up cycling –

Taking waste and turning it into something of value – the ubiquitous plastic bag and converting it into useful nanotubes. According to V G Pol, a scientist at ANL, Illinois, USA, this method is called "re-mediation". Gram pieces of high density or low density polyethylene are heated at 700^0C for two hours in the presence of a catalyst, cobalt acetate $[(CH_3COO)_2 Co]$ the mixture is allowed to cool. Multi-walled nanotubes grow on the surface on the surface of catalyst surface. Carbon nanotubes are extremely thin with a diameter 10,000x less than a strand of human hair.

These hollow cylinders made of C-atoms are extremely strong, have good thermal conductivity and are used in electronics, optics etc. These nano tubes were used as anode for Li-ion batteries. 1 Upcycled plastic from a grocery bag (3-6gram) can produce nanotubes (1-3gram) enough for one cellphone battery, which could suffice as an anode for one Li-ion rechargeable battery. It's thought that the same technology sans a catalyst could be used to grow spherical 2-10 µm carbon bodies, which have applications in printers, toners, filtration technology and the pain and tyre technology.

PAPER FROM ELEPHANT POO

As world leaders haggle over C-emissions cuts at Copenhegan summit on climate change, is there anything at all for us – the lay citizen – to do about reducing our C-footprint? And graduating to paper made of camel and rhino employed in Udaipur excrement?



We'd be in good company. In 2002, former US President George W Bush was reportedly gifted a box of elephant dung writing paper by former Sri Lankan PM Ranil Wickeremesinge. The use of handmade paper is catching on as people realize that ordinary paper means cutting more trees – 17 trees to go into making one tonne of paper. For making handmade paper, elephant dung is considered the best because it has lot of fibre. An elephant excretes > 1/2 of all that it eats, so the fibres are soft and long. We're talking enormous quantities here. A panchyderm eats ~ 200kg of food everyday and generates up to 50kg of dung, quite enough to manufacture 115 sheets of paper. In accordance with the report of Mahima Mehra, proprietor of *Haathi chaap*, Sanganer (Jaipur), 'The Good earth' that the paper (mix of 80% elephant dung & 20% cotton rag) may be brown, as bleaching to whiten the paper is not employed. Manufacturing process involves washing, boiling, disinfection and drying. Dried mass is beaten into a pulp and mixed with H_2O and dried flat into paper.

Beyond dung 'green paper' all kind of waste can be used from hosiery, rice, jute, silk, etc. "Banana trunk paper is fine and is used to make lampshades by manufacturers in AP. There are a hit with corporate, despite being more costly," reported Rao R. Narayan Moorthy, secretary general of the IPMA, admits the industry is becoming increasingly agro-based. "> 0.25 million hectares of mainly degraded land have been brought under pulp wood plantation. Further, planting on a 50-60,000hectares annually is on. "

GREEN BUILDING CONSTRUCTED

Many of us these days ask questions like what's the importance of going in for a green home? How would we define a green building? What are those simple steps we can take while building a house to reduce the C – foot print? What are the obvious and not so-obvious benefits of going green on construction, and how does it compare over a conventional house? There are many other different ways of building. It's possible to stop completely the use of many materials that builders can't do without it. It's possible to build with no bricks, no electric geysers for hot showers, no concrete blocks, no clay blocks, no vitrified tiles or ceramic tiles, no chemicals for water treatment and for swimming pools, no toxic paints, no chemical base water proofing. We can go even further. For captive power generation, let us diesel gen sets. For lighting in homes let us use fluorescent tube lights and not incandescent lamps. During construction we can do without lime-rendering for our walls, without regular ceiling fans at 75 watt and without bore wells for water. It's eminently possible to do residential buildings with no use of sand for construction of walls and roofs.

We can switch to using non cement alternatives for mortar. We need to be constantly innovating. It's important for us to understand why building blocks have been made the way they have been made so far. Let us also begin to understand that for every material we use, what the energy component is in the upstream stages of its manufacture-so we know what is the embodied energy used. Let us be mindful of the distance from which we buy our materials, for transport energy counts too in stacking up such C-costs of building. We need to breakdown every embodied energy component of material that we use in buildings. In doing all the above and more reality sector may end up asking more question than we can answer. While seeking to increase the use of materials with a higher renewable base, we should see how the economics are still compatible, foe we can't build at costs that are any higher financially than it's being done now and by others, while it's important for us to see that it's ecologically not expensive. Green buildings are not about a set of formulae that offer pat solutions. Nor is it about government regulation statutory demanding that we do something that they want us to. This is about our long term viability as a company and as an engineering or design professional. This is about how we reinvent ourselves and our company. This is about creating an environment that is conductive for growth of our cities into the future. This is about recognising the grim reality before us that as a builder we are not going to have limestone available just as easily available as it was the last 50 years for cement manufacture. It is about realising every material that we use that is extracted from Earth has got to be conserved or used judiciously-if, that is, we want this to be available beyond us and our generation of creators, for inherent in such man-made creation is destruction. All this will require working together.

It's not just that the building industry need to respond to this with a sense of urgency that our cities need today. It's for the government too. To wake up to some of these needs in a way that they encourage the environment for a builder with conscious approaches that don't offer subsidies and concession.

INNOVATIVE OPTIONS FOR BIOENERGY GENERATION & CARBON SEQUESTRATION

Biomass is a substance which refers to the variety of organic matter that can be utilized as source of energy, often through combustion or the production of gases and liquid fuels. Biogas, biodiesel and ethanol fuel are some of the current buzzwords among energy investors not only because of record-high oil prices and periodic turbulence in international relations, but also because they represent viable long term alternatives to fossil fuels. There is also need to move away from non-renewable energy sources viz. Solar, wind, biomass energy etc. If sustainably produced, some sorts of biofuel can allow significant reductions in carbon emissions and dependence on energy from abroad, as well as providing a boost for many domestic economies, particularly in the agricultural sector.

Though fossil fuel reserves are depleting and combustion is associated with the generation of many environmentally unfriendly end products (viz. CO_2, NOx, SOx, soot and fly ash) but still the combustion of fossil fuels for the time being seems to be inevitable source of energy to meet the ever expanding demand of energy hungry civilization. Power plants and transport are responsible for emitting huge amount of GHGs as both still rely heavily on fossil fuels. Many energy intensive and costly technologies are well in use in dispensing these end products but there is a need to develop a cheap and energy free process not only to control/dispense the end products of fossil fuel burning but if possible to convert them into some useful by products. The easiest way to eliminate gases particularly given off by coal-burning power plants is nature's way, through photosynthesis. Researchers are now hoping to marry the two together with an emerging technology that uses a bi-product of one to supply fuel to the other. At the heart of the technology is cylinders full of algae, which can gaseous emissions from a power plant's exhausted and convert it into biofuel thus a win-win on both sides it seems. Algae thrive in moist or wet environments, and through photosynthesis consume NOx and CO_2, and release clean air. Algae are the fastest plants on the earth and are rich in oil. The idea of algal photosynthesis to fight pollution is not new. US Department of Energy conducted a large-scale study several years ago which demonstrated that more than 300 species of algae were well suited to the task. However, implementation of such a process has always been hindered by logistics and cost considerations. Because photosynthesis efficiency is driven by complex cellular mechanism that depend on having just the right exposure to light – not too much, not too little – past algal systems grew to be complex and ultimately too expensive for most industrial sites to contemplate. They either took the form of huge, shallow ponds with extensive pumping and distribution mechanism, or conversely they develop into precisely engineered closed bioreactors with high manufacturing and maintenance costs. For centuries algae has been used as manure. It can be used to make biodiesel and by some estimates can produce vastly superior amounts of oil, compared to terrestrial crops grown for the same purpose.

Sixty % of rural India lives in utter poverty with no electricity. Rural Indians uses 180 million tonnes of biomass every year for cooking, creating indoor pollution and health hazards.

Making available locally grown clean and renewable cooking and lighting fuel can improve the quality of rural life. Liquid fuels are far superior to solid fuels for cooking because of their clean combustion, higher energy density and existing supply chain convenience. Ethanol is one of the best as it is an excellent substitute for kerosene and burns better, with no particulate output or unpleasant smell. Its combustion is almost as clean as that of LPG. Ethanol can be produced from any sugary or starchy material and is presently produced world over from sugarcane and corn. However, as the ethanol economy grows, there is a need to produce it from a crop which uses much less water than sugarcane and also produces food. Sweet-stalk sorghum (Jowar) is one of such crop. Its ear head produces grain which can be used for making bread; its sweet stem has nearly the same amount of sugar as in sugarcane and hence the juice can be fermented and used for ethanol production. The bagasse, left after juice extraction together with leaves is excellent fodder for animals. So from the same piece of land one can get food, fuel and fodder. Besides, sweet sorghum uses nearly 50 % less water than sugarcane to produce the same amount of sugar. Also the energy output/input ratio of producing ethanol from sweet sorghum is very positive. Nimbkar Agricultural Research Institute (NARI) introduced sweet-stalk sorghum in India in late 1960s and has developed the technology for its production and usage as a cooking and lighting fuel. An efficient ethanol cooking stove running on 50 % ethanol-water mixture has been developed. This mixture, which can be distilled efficiently in a rudimentary rural distillation unit, is safe and has less flammable fuel than pure ethanol. The stove works just like a LPG stove with high and low flame settings. NARI has also developed a lantern running on ethanol. It burns cleanly without smoke or smell. The ethanol lantern produces light equivalent to that from a 100W bulb. Presently the government is propagating solar lanterns running on PV cells. They use compact fluorescent lamps (CFLs) producing light equivalent to that form a 40W bulb. The CFL, lanterns are only twice as efficient as ethanol lanterns when we consider the power plant-to-light efficiency. With a little more R & D, we could make ethanol-based lanterns more efficient than electric lighting. In the absence of grid electricity to most rural areas, liquid fuel lanterns running on ethanol provide an attractive alternative. The use of ethanol for rural applications will also create great wealth in rural areas in terms of growing crops and producing ethanol from them. Another unique way in which ethanol can be used for lighting in rural areas is via electricity generation though two wheelers. For this, existing two-wheelers need to be converted to a hybrid vehicle where the small internal combustion engine running efficiently on ethanol or petrol charges the battery to run the electric motor system. When the vehicle is not running the system can act like a power plant producing electric power. Every two-wheeler can potentially become a mobile power plant. Can algae save the world again? Algae' farming for oil is the next biggest opportunity for the Biofuel industry. Algae, like corn, soybeans, sugar cane, Jatropha, and other plants, use photosynthesis to convert solar energy into chemical energy. They store this energy in the form of oils, carbohydrates, and proteins. The plant oil can be converted to biodiesel; hence biodiesel is a form of solar energy. The more efficient a particular plant is at converting that solar energy into chemical energy, he better it is from a biodiesel perspective, and algae are among the most photo synthetically efficient plants on earth. The microscopic green plants (algae) cleaned up the earth's atmosphere millions of years ago and it was hoped that they can do it now by helping **GHGs** and create new oil reserves.

In the distant past, algae helped turn the earth's then inhospitable atmosphere into one that could support modern life through photosynthesis, which plants use to turn CO_2 and sunlight into sugars and O_2. Some of algae sank to sea or lake beds and eventually became oil. All we're doing is turning the clock back. The race is now on to find economic ways to turn algae into vegetable oil that can be made into biodiesel. Jet fuel, other fuels and plastic products. We have started harvesting sunshine directly using algae, and extracting that stored bioenergy in the form of oil from the alga and then employing that to make biofuels and other non-petroleum products. [Many companies are working on algae and biofuels including USGSE, OO, BCEPA and some others.] Among uses, Japan Airlines had already a test flight with a jet fuel and biofuels blend including algae oils. Now that the reality of climate change has been accepted even by its strongest sceptics, there is rush to find answers. The latest buzz is to substitute the use of GHG-emitting fossil fuels with biofuels – fuel processed from plants. There're two kinds of biofuel: Ethanol **(C_2H_5OH),** processed from sugarcane or corn, and biodiesel from biomass. Climate-savvy Europe gave the first push to biofuel, mandating they should contribute 6% of fuels used in vehicles by 2010 and 10% by 2020. The bulk of biodiesel came from domestically grown rapeseed. But to meet its escalating needs, it looked at importing soyabean-based fuel from Brazil and Argentina, and palm oil from Indonesia and Malaysia.

It's to be remembered that climate change isn't a technological fix but a political challenge. Biofuel is part of a new era.

While so many researches are being pursued currently on a number of bio-feedstock for biodiesel production, algae have emerged as one of the most promising source of biodiesel production to reduce the burden of oil crises and fast depleting fossil oil reserves. Countries should be encouraged to make efforts into farming and research on suitable renewable feedstock such as algae, corn, soyabean, jatropha and other desired plants. These feedstock store energy in the form of oil, employ photosynthesis to convert solar energy into chemical energy. Viewing biodiesel perspective, algae are among the most photosynthetically efficient plants on earth. Just by way of history, petroleum is widely believed to have had its origin in kerogen, which is easily converted to an oily substance under condition of high **T/P**, kerogen gets formed from algae, **BOC,** plankton, plant material, bacteria etc by biochemical/chemical reactions such as diagenesis and catagenesis. Such an approach contribute to solving two major problems: air pollution from **CO_2/CO, SO_2** and **NOx** evoluting and future crises incurred due to shortage of energy sources. Many algae are exceedingly (up to 80%) rich in oil. Biodiesel production from this algal microflora possesses the beneficial by-product of reducing carbon and **NOx** emissions from power plants. **TAGs**, a component of algae besides proteins, carbohydrates, fats and **NAs,** via a simple transestrification reaction (in the presence of acid/base and **CH_3OH),** is converted into biodiesel. Vast number of the algal species viz. *Spirogyra aequinoctialis, Anaena azollae, Oscllatoria prolifica, S crassa, Chlorella sp., Ulotherix Sp., Hydrodictyon sp., Chlamydomonas Sp., Cladophora Sp., Scenedesmus perforates, Vaucheria sp., diatoms……*have found their utility in generation of biodiesel which is similar to biodiesel as produced from vegetable plants/plants oils. The difference is however in the yield of oil, and hence biodiesel. Besides, the production of algae is sustainable and don't require as much area and time as crop.

Energy security is one of the prime concerns of any developing/developed Nation and India ranks 6th in the world in terms of Energy demand, accounting for 35% of world commercial demand in 2001. During 2004-05, country imported 95.86MT of crude oil valued at US£26 billion. As the Indian Economy is expected to grow at a rate of over 6%/annum and petroleum imports are expected to rise to 166MT by 2019 and 622MT by 2047, so there is a growing need for energy security. With the increasing energy demands, it has become imperative to look for renewable sources. Biomass has the potential to become a significant source of renewable energy. Technologies that convert fibre, starch and sugar from trees, woody plants and crops, and food processing residues into useful biofuels are witnessing important advances in R & D. Nations and communities that are rich in these renewable biomass resources have the burgeoning to become energy independent and economically robust. Traditionally biomass can make a useful contribution to bioenergy production and in recent year's cutting edge research is being carried out for alternative biofuel production – bioethanol and biodiesel. Biomass **R & D** must now move beyond enhancing conversion technologies alone and bioengineering tools to redesign the feedstock for specific products. Bioengineering offers a prospective to overcome the limiting barriers for commercialization of this expertise, as these gizmos would find efficacy in developing a integrated product devise strategy where feedstock and bioconversion can be so designed, to allow optimal interaction in the system.

Such an integrated-interdisciplinary approach would be vital in making technical and economical breakthrough in biomass utilization, contributing to the development of a sustainable renewable energy platform. It's quite advisable that an important research component of any biofuel program should include improving sustainability and the added benefits of carbon sequestration. The potential for dramatic improvement in sustainability can be achieved via several avenues of research. Sustainability research will require a need to identify

- -plant traits and other factors that enhance asymbiotic and symbiotic microbial processes;
- - plant traits that enable efficient resource applicability;
- -conditions that optimize the amount of nutrients supplied by the activities of symbiotic and associative microbial communities;
- -the importance of microbial functional diversity and its interdependence on plant diversity;
- -plant and microbial traits that enhance carbon sequestration; and
- Methodologies for preventing age-related yield decline.

Research needs to deepen understanding of the mechanisms and genetics underlying plant-soil-microbial interactions and associations. The need of encompassing research scale ranging from metagenomics and proteomics of endophytic and soil-derived diazotrophic bacteria and their habitats to the phenotypic expression of symbiotic traits gets paramount importance. Success can be evaluated by identifying the relative contributions of plant feature vs. environmental conditions for expression of targeted pathways, requiring use of **HTP** methods of molecular biology, molecular imaging, and the development of molecular probes. Further, these studies need to integrate lower scale findings into measures of the growth and production of biofuel crops, feedstock quality, and the symbiosis of associative endophytic and free-living microbes.

Algae have much commendable strength as renewable energy resource. Unlike many land-based bioenergy crops, they don't require the use of large areas of agriculturally productive or waste or industrial sites. Marine sites may also be possible. In addition, algal growth can be directly coupled to other industrial processes, in particular the scrubbing of **CO_2** from **FG** and the removal of nitrates and phosphates from waste water, which not only has a cost benefit, but can reduce **CFP** of conventional industrial processes. Furthermore, algal cultures can be employed for the production of a number of high-value products (like spriulina, a blue green algae- producer of a very good sweetener), and algal species mentioned in the text are capable of direct production of high levels of **HCs.** Of the many approaches that researchers have proposed to grapple with the problem of increasing carbon emissions, **CO_2** sequestration holds considerable promise. It involves capturing **CO_2** emitted from industrial smokestacks and other sources and storing it in a stable and environmentally harmless form. It's like locking up the **CO_2**, so that it doesn't enter the environment and thus it's not available for **GH** phenomenon and other chemical combinations. The potential cages for this purpose are spent oil and gas reservoirs, underground geological formations, vast grasslands, oceans etc. an Italian scientist, Cesare Marchetti in the late seventies, pioneered the idea of **CO_2** sequestration. Natural **CO_2** sequestration has been going on in vegetation (**CO_2** needed by plants to synthesize their food) and in oceans for millennia.

Oceans hold **>50%** as much **CO_2** as the atmosphere. **CO_2** sequestration has one major advantage that it doesn't need any substantial changes in the world's energy infrastructure.

GREEN PLASTIC FOR BETTER DEPORTMENT

The slow biodegradation rates of plastic materials have created a need for alternative materials with physical and industrial properties similar to petrochemical derived plastics but well biodegradable. Bioplastics are natural polymers synthesized and catabolised by various microorganisms and accumulate in microbial cells under stress conditions. Unlike petroleum- based plastics, bioplastics are eliminated from our biosphere in an environment friendly fashion. These can be conventionally managed and recycled and landfilled, or incinerated so that neither leaves plastic litter nor leads to depletion of our finite resources (fossil fuels). Moreover, these are helpful in reducing carbon footprints by as much as 40%.A number of bioplastic based on cellulose, starch and poly lactic acid (PLA) are common now a days. Starch is an inexpensive material derived from corn and other crops, and is an annually renewable source. Starch-based bioplastics can be produced by blending thermoplastic starch with biodegradable polyesters like polycarpolactone (PCL) to increase its flexibility and resistance to moisture and then can be used for foaming and injection molding. By fermentation of starch from crops, commonly cornstarch or sugarcane, lactic acid is produced which can be polymerized to produce PLA. Similarly, cellulose based plastics require wood pulps. Apart from these plastics, a number of water-soluble bioplastics are being developed like carboxymethyl cellulose (CMC), hydroxyethyl cellulose (HEC), pullulan, thermal polyaspartate (TPAs), etc. by modifying starch and cellulose. These are being developed to replace the water-soluble polymers prepare from synthetic monomers like acrylic acid, maleic anhydride, methacrylic acid and also by the combination of these chemically derived monomers. Water-soluble polymers are not biodegradable, and persist in ocean, lakes, and other water depositories resulting in water pollution.

On the other hand, water soluble BPs derived from modification of starch and cellulose have good moisture retention capacity and low oxygen permeability, so they easily degrade under water. Polyhydroxyalkanoate (PHA) materials are the most popular types of bioplastics. They are a complex class of polyesters synthesized by most genera of bacteria and members of the family Halobacteriaceae of the Archaea. Most of these prokaryotes synthesize poly 3-hydroxybutyric acid and other PHAs as storage compounds and deposit these polyesters as insoluble inlusions in the cytoplasm. When the cells experience a nutrient imbalance such as excess carbon with limited nitrogen, phosphorus or sulphur, PHA accumulation starts as has been shown in *Ralstonia eutropha*. The same microorganism also produces the enzyme PHA dipolymerase to break down the polymers into monomers, metabolized as a carbon source. PHB or poly hydroxyl butyrate is the most common type. However, it is a relatively stiff and brittle bioplastic and is of limited use. It can be made more flexible and tougher when copolymerized with a fraction of long chain monomers such as 3-hydroxyhexanoate (HH) or 3-hydroxyvalerate (HV), etc. and is used in wide varieties of products like containers, bottles, razors and materials for food packaging along with many medical applications such as implants, gauzes and osteosynthetic materials. In the bacterium *Ralstonia eutropha,* which is a natural PHB producer, PHB synthesis requires three enzymes and their gene products. All the three enzymes are known to locate in the cystol of the cell where PHB accumulation takes place. When the bacterium is supplemented with propionate along with glucose in the production of a copolymer [P (HB)-(HV)]. This decreases the crystallinity, stiffness and melting point of PHBs making them more suitable as commercial products.Besides *Ralstonia eutropha,*some other strains of bacteria like *Pseudomonas putida, Comamonas acidovorans* and *Bacillus megaterium* have also been well exploited to produce these kinds of polymers. However, the major limitation associated with the production of bioplastics in bacteria is the high cost when compared to the petroleum-derived plastics. Potentially, in turn, the plant offers an alternative approach to synthesize these bulk commodity products at low cost. Whereas PHA production in bacteria and yeast requires costly fermentation process with an external energy sources such as electricity, in plant systems it is considerably less expensive as it relies on water, soil nutrients, atmospheric CO_2 and sunlight. In addition, a plant production system is much more environment friendly. While in bacteria PHB synthesis and its accumulation is limited in the cystol, in plants PHB can be produced in a number of subcellular compartments like cystol, plastids, mitochondria and peroxisomes. *Arabidopsis thaliana* was the first plant to be used for PHA production. In *Arabodopsis,* a small amount of PHB production was first demonstrated by expressing in its cytoplasm two enzymes (acetoacetyl-CoA reductase and PHB synthase) from the bacterium *Ralstonia eutropha*. The polymer produced was of high molecular weight and similar in structure and properties to PHB but the yield was low (1% of dry weight of leaves) and plants were stunned in growth. The yield was later increased from 1% to 14% dry wt. By expressing PHB biosynthetic pathways in the plastids. The achievement was ground breaking, producing one transgenic plant with 14% dry wt. of PHB in its leaves. Later on, low amount of medium chain length PHA copolymers were synthesized in peroxysomes by polymerization of 3-hydroxyacyl-CoA intermediate generated by degradation of fatty acids in peroxisomes of *Arabdiopsis* plant.

After the success of synthesizing PHB in plants, PHBV copolymers were produced in both *A. thaliana* and seeds of *Brassica napus* (oilseed rape). This was one of the most remarkable feats of metabolic engineering yet performed in plants, requiring the expression of four bacterial genes (ilvA, $phaA_{rc}$, $phaB_{rc}$, $phaC_{rc}$) and modification of independent metabolic pathways (fatty acid and amino acid synthesis). But this also resulted in the lower amount of copolymer production (2.5% dry wt.) compared to PHB synthesis (14% dry wt.). The reason was not clear but it had been suggested that modifying the isoleucine pathway created a metabolic burden on the plant, which decreased PHA yield. A number of other plants like Nicotiana, Brassica, Gossypium, Medicago and Elaeis have also been well exploited for synthesizing a variety of PHAs. In tobacco, by expressing in its plastids phaA and phaB genes of *R. Eutropha* and phaC gene of *Aerommas caviae,* it was also possible to produce 0.09% dry wt. of PHAs. The yield was ten time more as produced in cytoplasm on Nicotiana if phaA gene alone from bacterium *R. Eutropha* and phaC gene from *R. Eutropha and* phbC gene from *A. caviae* were expressed. Plastic is often used to improve the mechanical properties of fibre-based composites. In case of cotton, *R. Eutrpha* pha genes when successfully expressed in the cystol of its fibres, the fibres from its transgenic plants contained 0.34% PHB, which was sufficient to improve the insulating properties of the fibre. Similarly, in stems of transgenic flax (*Linnum usitatissimum*), bioplastic has also been produced with an aim to improve the quality of fibre rather than providing a plant source of PHB for extraction. Interestingly, seed production as well as plant growth and morphology were found to be enhanced in these transgenic plants.

At commercial level, the approach to convert plant sugar into plastic was first adopted by Cargil, an agricultural business giant, and Dow Chemicals in corn and other plants to produce a plastic called PLA (polylactide). Later on, other companies including ICI (Imperial Chemical Industry) developed ways to produce a second plastic, called PHA. Like PLA, it is made from plant sugar. Whereas PLA requires a chemical step outside the organism to synthesize it, PHA naturally accumulates within microbes as granules that constitute up to 80% of single cell mass. Following this, big industrial giants like Monsant tried to produce PHA using another approach – growing plastics in the plants. This required the modification of genetic make-up of agricultural crops and was achieved by the collaboration of researchers at Michigan State Universiity and James Madison University in 1992 when they genetically engineered *A. thalina* plant to produce a brittle type of PHA. But this plastic turned out to be very costly than fossil fuel based counterparts. However, the challenges of separating the plastics from the plants, too, are formidable. All the processes required to isolate plastic from corn stover consume even more fossil fuel than most petrochemical manufacturing routes. The only plant based plastic that is being commercialized is Cargill Dow's PLA. The hope behind green plastics research is to find methods of producing commercially viable replacement for petrochemical polymers through the metabolically engineered action of plants. Thus, researchers have turned toward plants as being a potentially cheaper and more convenient method of producing renewable, biodegradable plastics. A broad range of PHAs covering a spectrum of physical properties have now been synthesized in plants. The challenge for the future is to succeed in high-level production (15% dry wt.) of a limited number of useful PHAs and in developing efficient extraction processes.

BIOFUEL FROM PULPWASTE

Pulp and paper industry is among the major sources of industrial pollution. But they could soon double as biorefineries. The Swedish company Chemrec has developed a process for turning the black liquor left over from pulp and paper bleaching into a clean-burning synthetic fuel. The biofuel generated with Chemrec's process, dimethyl ether (DME), can be used as a replacement of liquefied petroleum gas (LPG) and diesel. This is particularly significant in view of the ecological impacts of biofuels production and the disruption caused to food production, as brought out by recent studies. A study European Union (EU) has shown that second-generation biofuels such as DME made from biomass gasification provides the highest GHG reduction for the lowest cost. In the Chemec's technology, gasification process that turns black liquor into a mix of CO, H_2 anCO2 called synthesis gas or syngas, for short, is adopted. Pulp mills already take care of gathering loads of biomass, and, as a liquid, the waste liquor is easier to feed into gasifier than are solid chunks of biomass. In practice, however, this waste has proved tough to gasify. Black liquor is particularly difficult to deal with because of the highly caustic inorganic chemicals, such as NaOH, employed to break down the pulp. In Chemrec's reactor design, black liquor and pure O_2 injected in from the top feed at $1,800^0$C fireball at the centre of the reactor. Most of the dissolved wood in the black liquor forms syngas and flows out of the reactor.

MACHINES RUN BY MICROBES

It's the rise of the machines, literally. The first microscopic mechanical devices to successfully incorporated living microbes together with inorganic parts by rocking bacteria to power rotary motors, livescience.com reported. In future plans making of micro-robots driven by biological motors would be possible revealed by Yuichi Hiratsuke, a nano-biotechnologist at the UT. It has been experimented with one of the most rapid crawling bacteria, Mycoplasma mobile. This pear-shaped microbe, a millionth of a metre long, gliding over surfaces at up to seven-tenth of an inch an hour, translated to a 6-foot-tall runner equates 20mph. Circular pathways coated with sugary proteins were built, which the microbe needs to stick to in order to glide over surfaces. They then docked a rotor onto the track and coated the bacteria with vitamin B7, which acts like glue to yoke the germs to the cog. Also microbes were genetically modified so they stuck to their track more stably. Roughly 20,000 rotors on a Si-chip have been created. Each cog is etched from silica, which sand is made of, and is 20µ wide, or roughly a fifth the diameter of a human hair. The rotors spun at ~1.5 to 2.6revolutions/minute. Each individual cell in these motors generates ~ 10,000x less torque than conventional microscopic electronic motors can. It has been suggested by researchers that these systems could repair themselves and require only the sugar glucose as fuel. In the future, instead of live bacteria, use of dead ones to avoid the potential biohazards living microbes pose, has been suggested.

BACTERIUM DECONTAMINATING SOILS AND GENERATING ELECTRICITY FROM MUD AND WASTE

Fuel cells which use microorganisms to convert chemical energy to electrical energy are seen as one of the future source of clean power. Microbes' capacity to extract electricity from mud and wastewater, have been known by various researchers.

Dereck Lovley and teammates from the UM, USA, found the microbe, Geobacter, which absorbs metals from the soil (bioremediation) for its metabolism, in the sediments of Potomac River, in the US in 1987. In 2002, another ability of Geobacter was stumbled, having the potential to generate electricity. After some thorough studies, the reason has been traced in 2005. The conductive pili or hair-like filaments located on the surface of the cell ware found to transfer electrons from the metals absorbed. The geobacter was grown on a graphite electrode; provided an organic substrate (-acetate) as food allowing a biofilm to develop. Then a 400mv current was passed through the electrode. This induced Geobacter to transfer electrons and generate power. Gradually Lovley's team witnessed the growth of a new strain of the microbe that dramatically increased the transfer of electrons and the power output up to 8 times.

The findings reported in the August issue of *Biosensors and Bioelectronics*, open the door to improved microbial fuel cell architecture. As a conservative estimate, the output was increased 8-fold, breaking through the plateau in power generation that has been holding back in recent years. Now there is a whole range of applications that microbial fuel cells can be put to: converting waste water and renewable biomass to electricity, treating a single household's waste for producing electricity powering the house, mobile electronics, vehicles and bioremediating contaminated environments. In 2007, the UC, in Australia, designed a microbial cell in collaboration with FBC, with a 10L capacity, converting the brewery's waste into clean water and electricity.

PAPER-PULP BATTERIES

Ordinary paper could one day be used as a lightweight battery to power the devices that are now enabling the printed word to be eclipsed by email, ebooks and online news. Researchers at Stanford University in California reported successful turning paper coated with ink made of Ag and C-nanomaterials into a "paper battery" that holds promise for new types of lightweight, high performance energy storage. The same feature that helps ink adhere to paper allows it to hold onto the single-walled C-nanotubes and Ag-nanowire films. Earlier research found that Si-nanowires could be used to make batteries 10x as powerful as Li-ion batteries now used to power devices such as laptops. This type of battery could be useful in powering electric or hybrid vehicles, would make electronics lightweight and long lasting, and might even lead someday to paper electronics, the researcher added. Battery weight and life has been an obstacle to commercial viability of electric-powered cars and trucks.

ENERGY FROM WINERY WASTE

American and Indian researchers have come up with a new technology that generates electricity by using the waste from improper fermentation. In accordance to them the technology could provide a new and cost effective way to clean wastewater from wineries and get some vale out of a "bad bottle of wine". Two groups of bacteria available in winery waste were found. One group of bacteria turns unused sugar and unwanted vinegar from improper fermentation into electricity, while the other uses that electricity to spilt water molecules into oxygen and hydrogen, which escape into the atmosphere. Recently a microbial electrolysis cell at a winery in Nap Valley, California has been installed by Bruce Logan, a researcher at PSU.

Sheela Berchmans of CERI in Karakudi, TN, also claimed to have generated power by using the same methodology, the LiveScience website reported. Sugars like glucose, alcohols and effluents containg sugars or alcohols can be used (to produce electricity) stated Berchmans, who recently co-authored a paper in the journal of Environmental Science and Technology. In accordance with the report, the two groups of bacteria identified as Acetobacter aceti and Bluconobacter roseus – can spoil wine. The researchers at CERI, who created microbial fuel cells using single cultures of each as well as both together, produced 859 milliwatts of power. It is being hoped that the technology could eventually be scaled up to produce more electricity or help to save electricity that would normally be used to treat wastewater.

COOKED BY SUN

Methane, an important constituent of cooking fuel, can now be manufactured in large quantities. All we need is a nanotube catalyst, carbon dioxide, water and lots of sun. Researchers used titanium dioxide to create nanotubes ~135mm wide and 0.1mm long. Steel tubes were filled with carbon dioxide and water vapour covering the ends of the containers with a film of nanotubes. When sunlight fell onto the nanotubes, water and carbon dioxide combined to form methane. The devices generated ~160 micro litres of methane/hour/gram of the nanotubes. This method can not only be an important generator of fuel but it might also help control emissions by using carbon dioxide from sources like a coal plant. The findings were released in the February (2009) 5 issue of *Nature*.

PLATINUM FREE FUEL CELL

Fuel cells are, in principle, the most efficient way to convert hydrogen fuel into electricity. Conventional fuel cells consist of two electrodes coated with a Pt catalyst that splits hydrogen fuel into acidic hydrogen ions from one side to the other, creating an external electrical current. The use of Pt makes conventional fuel cells very expensive, but cheaper metals simply can't withstand the harsh acidic environment of the fuel cell. Now researchers in China have come out with a fuel cell that uses a new membrane material and eliminates the need for an expensive catalyst. The polymer used as membrane in the new fuel cell is comparable in structure to the highly conductive polymer Nafion (a sulphonated tetrafluoroethylene coplymer) that is used in conventional acidic fuel cells, but is less expensive than Nafion. The new fuel cell uses a Ag cathode and an anode coated with Ni nanoparticles decorated with Cr as the catalyst. The fuel cell works by reacting hydrogen and oxygen to create hydroxyl ions and water, catalysed by the Ni anode. The hydroxyl ions are conducted across the polymer membrane, generating an external electrical current. At present the power output of the new fuel cell is modest-about 50milliwatts/cm^2 at 60^0C. But the first demonstration of an alkaline fuel cell that does not require expensive metal catalyst, it is an important proof of principle, researchers state.

VITAMIN C FINDS USE IN UNFAMILIAR TERRAIN

In a new application for disease-fighting vitamin C, researchers have used it to assemble fibre bundles of Au, Ag and Pt nanoparticles. Such bundles are used in new-age medicine to produce sensors for disease detection, enhancement of optical imaging and even manufacture of cheaper and pollution-checking catalytic converters.

According to the report published in Journal of Colloid and Interface Science Vol. 311 No.1, two methods are developed to produce fibre bundles of metallic nanoparticles with vitamine C. In the first method, ascorbic acid was allowed to degrade in acidic condition to form colourless fibres. Then, separately, made nanoparticles of Au, Ag and Pt were deposited on those fibres. In the second method, ascorbic acid was used as a reducing agent on salts of Au (hydrogen tetrachloroaurate) to form Au nanoparticles and subsequently grown into fibres. Using sophisticated imaging techniques like transmission and scanning electron microscopy, the assembly of nanoparticles forming composite fibre bundles were studied.

HYDROGEN FROM PEE TO FUEL CARS

Researchers have combined refuelling our car and relieving ourselves by creating a new catalyst that can extract hydrogen from urine. The catalyst couldn't only fuel the hydrogen-powered cars of the future, but could also help clean up municipal wastewater as reported by physorg.com. Geradine Botte of Ohio University uses an electrolyte approach to produce hydrogen from urine – the most abundant waste on the earth – at a fraction of the cost of producing hydrogen from water. Urine's major constituent is urea (NH_2CONH_2), which incorporates four hydrogen per molecule – importantly less tightly bonded than the hydrogen atoms in water molecules. Electrolysis was used to break the molecule apart, developing an inexpensive nickel based electrode to efficiently oxidise the urea. To break the molecule down, a voltage of 0.37V needs to be applied across the cell, which is much less than the 1.23V needed to spilt water. "During the electrochemical process the urea gets adsorbed on to the nickel surface, which passes the electrons needed to break up the molecule," Botte added Chemistry World Journal.

Storing pure hydrogen gas requires high pressure and low temperature. New nanomaterials with high surface areas can adsorb hydrogen, but have yet to be produced on commercial scale. MCD is working on a project to generate electricity from urine. For this, it will install around 1000 waterless urinal kiosks around the city. Process involved: Waste is collected from waterless urinals and transported to portable power plants. Water, hydrogen are produced from the decomposition of bio-degradable components of urine. Water is cleaned by reverse osmosis and can be used for industrial purposes, power is generated from hydrogen. 1 litre of urine makes 1kw of power, enough to light a 50W bulb for 20 hours.

INSTANT FUEL: HYDROGEN STORAGE MADE EASY

Hydrogen can now be conveniently used as fuel without the usual hassle of storage and distribution. A method has been developed to produce hydrogen on the spot for internal combustion engines from an alloy of Al and Ga. The alloy with 28 % Al by weight, has the potential to replace petrol given its high efficiency and lower cost o production, stated lead researcher Jerry Woodall of SECEPU, Indiana. The mechanism is based on a simple chemical reaction. When water is poured on the alloy hydrogen gas is released this gas is directly fed into the engine as fuel. The technology produces fuel instantly eliminating the need for transportation and storage. Hydrogen generating fuel cells from Al have an efficiency of 75 % as compared to 25 % of petrol-fed internal combustion engines. Here's how it works. When water is added, Al, which has an affinity towards oxygen, breaks it down into oxygen and hydrogen forming Al_2O_3.

The end products of the reaction are alumina and Ga along with water as a result of combustion of hydrogen in the engine. No toxic fumes are produced. Since hydrogen has a low MW, it has to be pressurised or liquefied to provide sufficient driving range. The mass of the tanks needed for compressed hydrogen in conventional engines reduces the fuel economy. In the alloy-fed motors, the chemical reaction is processed in a container, in which the by-products solid alumina with a liquid Ga core remain with water. By recycling this by-product, fresh alloy is manufactured in the best way. The technology is suitable for small internal combustion engines like portable emergency engines, lawn mowers and chain saws.

CLEAN FUEL FROM SEWAGE

Biofuels extracted from human waste will now replace petrol and diesel in buses across Oslo (Norway). The city' two sewage plants will crank out the bio-CH_4 (an environment-friendly, C-neutral renewable source of energy) from Bekkelaget sewage treatment plant. The new buses to be introduced by 2010 in the Norwegian capital will run on this biofuel, which is generated by fermenting sludge. Bio-CH_4 has been found to emit 78% less Nox and 98% fewer fine particles and is 92% less noisy. It's observed that by going to the wash room, a person produces the equivalent of 8L of diesel/year. Hence, the sewage from large number of houses, when converted to bio-CH_4, can be used to operate as many as 80 buses for 100,000km each.

DIESEL FROM FUNGUS

A reddish microbe found on the inside of a tree at a secret location in the rain forests of northern Patagonia could unlock the biofuel of the future. Its potential is so startling that the researchers have coined the term "mycodiesel" – a derivation of the word for fungus – to describe the bouquet of hydrocarbons that it breaths.

"This is the only organism that has ever been shown to produce such an important combination of fuel substances," stated Gary Strobel (70 year-old veteran of the world's rainforests), a professor of biology at MSU. "The fungus can even make these diesel compounds from cellulose, which would make it a better source of biofuel that anything we use at the moment." The study appeared in a peer-reviewed British journal, *Microbiology*. It's established to come across *G roseum* thanks to "two cases of serendipity". The first was in the late 1990s, a previously unidentified fungus called *M albus* came across. By sheer accident, it was found that *M albus* releases a powerful VOC – meaning gassy- antibiotic. Intrigued by this, the team tested M albus on the ulmo tree, whose fibres are a known habitat for fungi, in the hope that this would show up a new fungus. Quite unexpectedly, *G roseum* grew in the presence of these gases when almost all other fungi were killed. It was totally surprised to learn about making a plethora of HCs and HCs derivatives, when gas composition of *G roseum* was examined. Biofuels have been promoted as good alternatives to oil, which is sourced from politically volatile regions and is a major contributor to the GHE.

UNCONVENTIONAL WASTEWATER TREATMENT STRATEGIES

- **Zinc Removal With Old News Paper**

Could the old news papers piling up in the storeroom help treat wastewater? Experiment has hown how newspapers can be used to remove heavy metals from industrial waste water.

This experiment focused on the connection between newspaper pulp and Zn. Used newspaper was processed in a $NaHCO_3$ (Sodium bicarbonate) solution to remove ink and other chemicals before being washed thoroughly. From there, the treated pulp was mixed with effluent from the electroplating industry that contained Zn, one of the leading sources of environmental pollution. The treated pulp was able to adsorb a significant amount of the Zn, leading researchers to conclude that the method was successfully applied for Zn removal and it was also a potential adsorbent for Fe, Cu, and Mn. While one of the most common elements on earth, Zn is dangerous in large concentrations. It finds use in antirust coatings, batteries and mixed into alloys and compounds that are used to make paint, wood preservatives, and ointments. Electroplating, which coats a metal that is electrically conductive with a thin layer of anther metal, often creates wastewater with high concentrations of dissolved Zn. While research into these treatments is still on, there is hope that it could be applied to industrial scales. Newspaper pulp is not the first waste product to show potential in filtering heavy metals from effluent water. Materials such as bamboo pulp pink bark, peanut shells and saw dust from teak, spruce and mango trees have all been tested at various times for their ability to adsorb heavy metals in waste water, and the results have been promising.

- **Green Solution to Turn Turbid Water Clear**

Tamarind seed kernel powder, discarded as agricultural waste, is an effective agent to make municipal and industrial wastewater clear. The present practice is to use Al-salt to treat such water. It has been found that alum increases toxic ions in treated water and could cause diseases like Alzheimer's. On the other hand kernel powder is not-toxic and is biodegradable and cost effective. For the study, four flocculants (chemicals that cause colloids and other suspended particles in liquids to aggregate, forming a floc) namely tamarind seed kernel powder, mix of the powder and starch, starch, and alum were employed.

Flocculants with slurries were prepared by mixing measured amount of clay and water. The result showed aggregation of the powder and suspended particles were more porous and allowed water to ooze out and become compact more easily and formed larger volume of clear water. Starch flocks on the other hand were found to be light weight and less porous and therefore didn't allow water to pass through it easily. The study establishes the powder's potential as an economic flocculants with performance close more established flocculants such as $K_2SO_4Al_2(SO_4)_3$. $24H_2O$ (potash alum). The findings of the study were published in December (2007) issue of *Bioresource Technology*.

- **Seaweed to Remove Chromium from Leather Effluent**

Two cost effective and eco-friendly techniques to remove Cr from the effluent discharged by tanning units have been developed by the researchers of CLRI, Chennai. The metal exists in its highly carcinogenic hexavalent form Cr (VI) in the effluent. Currently, chemical precipitation methods are employed to remove Cr, but they lead to the formation of chrome-bearing solid wastes, whose disposal again is a problem. Other methods available like membrane separation and ion exchange are expensive and also generate solid waste containing Cr. One of the method uses H_2O_2 (Hydrogen peroxide) with a zeolite (a porous substance) and organic Cu-complex based catalyst to remove Cr (VI). This process removes Cr ~5x as fast as the other methods.

Being porous, zeolites offers far more sites for the reaction to occur, enabling recovery of Cr in less than one hour at 60^0C. Studies on commercial tannery wastewater, indicates that the catalyst can be recycled without any large change in its efficiency. The second method uses cheap, abundantly available seaweed, *Sargassum wegtii*. The seaweed added to a chrome tanning solution fully removed the heavy metal in 6hours. A maximum uptake of 35 mg of Cr/gm of seaweed was reported. Later, the chrome-loaded seaweed were used to make $Cr_2(SO_4)_6$ (chromium sulphate), which is a major tanning agent as reported in journal *Environmental Science and Technology vol.38, No.1,2004*. These methods are of special significance to the small and medium leather enterprises due to the cost effectiveness and environmental sustainability.

- **Junk Iron to Clean Polluted Water**

In 1983 the entire Mianus river bridge in Connecticut, US, collapsed when the bearings rusted internally. Rusting thus proved to be a bane. But a bane can be turned into a boon. A team of researchers from China used scrap iron to treat industrial wastewater contaminated with excess of N, P and organic dyes. In wastewater stable and unoxidised scrap develops a strong tendency to react with the pollutants and makes them more biodegradable. In other words while the iron oxidizes (rusts) it helps clean up the polluted water. In a series of experiments carryout since 2001, Luming Ma from TU, China and Wei-xian Zhang from LU, UK, successfully used scrap iron to treat wastewater from petrochemical, textile and pharmaceutical industries. During the full-scale application of the process in 2006, the iron-based reactor was connected to the biological treatment plant to be used as a treatment preceding the biological clean-up. It was found that N removal had gone up from 13 to 85 %. P removal increased from 55.6 to 63.3 % and up to 80.4 % of the colour was reduced. This partial degradation of polluted water using scrap iron helped in turn completely biodegradable. Conventional technologies like biotreatment and chemical precipitation are either ineffective or expensive. In chemical precipitation, chemicals are added to wastewater. They react with the contaminants and settle down.

The wastewater is then decanted. But this process requires continuous addition of chemicals and produces large amounts of sludge which is expensive to be disposed off. Biotreatment proves ineffective due to the highly toxic nature of the pollutants. The scrap iron technology is cheaper since iron scraps are readily available. It would be environmentally beneficial in providing iron scraps with a better role than simply dumping them in the junkyard.

- **Copper Removal with Peanuts**

For cleaning wastewater, peanut shella are an effective tool. The agricultural waste removes poisonous Cu ions from industrial wastewater. Though the industry uses many chemical methods to remove heavy metals from wastewater, most of them are highly expensive. This method seems to be cheaper and eco-friendly. Peanut shell cleans 95 % of Cu ions. Waste water from electroplating, pulp and paperboard industries contain Cu and affect marine and human life. For example, it can damage human liver. The study by Duygu Ozsoy and colleagues in the department of environmental engineering at the MU in Turkey was published in the *International Journal of Environment and Pollution, Vol.31, No.1&2, 2008.* Some other plants and plant products too have been used to clean wastewater.

Erythrodontium barteri. a moss, removes 97 % of Cu from wastewater, says astudu done at OOU in Nigeria, published in the International *Journal of Physical Sciences, Vol.2, No. 11, 2008.* The biomass waste traps all the positively charged heavy metal ions, the study explains.

BRAND NEW FRIENDLY BUGS TO TREAT EFFLUENT

Researchers from NEERI have discovered hundreds of hitherto untapped friendly bacteria from CEPS. This could completely revolutionise the way industries currently treat their wastewater. It would also help create a valuable metagenomic library of 'good bacteria' for everyone to use. CETPs, the biological wastewater treatment facilities, receive inputs from variety of industry. About 25 to 30 different kinds of bacteria work as a community and biodegrade the thousands of harmful chemicals in this wastewater. While genomics experts have extensively explored soil microbes, a very few studies have been carried out to map microbes responsible for converting harmful compounds into harmless ones. Such studies assume importance because CETP sludge receives wastewater from different industries with individual market-driven demands. Exploiting the 'over-looked' genetic resources might revolutionise methods used to degrade recalcitrant and xenobiotic pollutants that do not get degraded by known culturable bacteria. The team detected a total of 76 culturable and over 200 unidentified strains. Strains to identify antibiotics that could kill certain bacteria in microbial ecosystem will also be studied.

PERSPECTIVE AND FATE OF GREEN CHEMISTRY

For the promotion of green chemistry, it's imperative to create a brand of green thinkers. Green chemistry should be of upfront consideration. Scholars of all levels must be made aware of the introductory ethics and philosophy of green chemistry. Educators should possess procedures and methodologies and need to equip themselves with training material, tools and similar infrastructures besides collaborations. For a successful implementation more and more green-school programmes as is run by CSE, New Delhi, must be created. Support in terms of tax incentives and awards for promoting green ideas.

Information, technologies transfer and approaching beyond sustainability would be welcome step in promoting the green chemistry.

Green Chemistry has the potential of wiping out the possible occurrence of tragedies like Bhopal Gas by paving way for safe eco-friendly environment. There is utmost need to emphasize on creating awareness about green chemistry not only amongst the chemists and scientific community but also industries and commercial institutions. Leading countries like USA, UK, Japan, Italy, Australia and other developed nations have given green chemistry top priority with a view to safeguarding their environment and economic interests. In India, it's in the inception stage and has assumed rapid strides embracing catalysis, benign solvents, renewable feedstock, green nano materials, biodegradable polymers and others. Educating the next generation of researchers and training in green techniques occupies a central theme in the outreach activities.

CONCLUSION

Green chemistry is not a new branch of science. It is a new philosophical approach that through application and extension of the principles of green chemistry can contribute to sustainable development.

Great efforts are still undertaken to design an ideal process that starts from non-polluting materials. It is clear that the challenge for the future chemical industry is based on production of safer products and processes designed by utilizing new ideas in fundamental research. Furthermore, the success of green chemistry depends on the training and education of a new generation of chemists. Student at all levels have to be introduced to the practice of green chemistry. Green Chemistry has the potential of wiping out the possible occurrence of tragedies like Bhopal Gas by paving way for safe eco-friendly environment. There is utmost need to emphasize on creating awareness about green chemistry not only amongst the chemists and scientific community but also industries and commercial institutions.

ABBREVIATIONS

USGSE: United States Groups Sapphire Energy; OO: Origin Oil; BCEPA: Bio Centric Energy and Petro Algae: GHGs: Green House Gases; O_2: Oxygen; CO_2: Carbon dioxide; NOx: Nitrogen Oxides; CO: Carbon monoxide SO_2 : Sulphur dioxide; TAGs: Triacylglycerols: NAs: Nucleic Acids; CH_3OH: Methanol; MT: Million Tons; R & D: Research and Development; HTP: Highthroughput; FG: Flue Gas; CFP: Carbon foot print; HCs: Hydrocarbons; T/P: Temperature and Pressure; BOC: Biodegradable Organic Compound; $(CH_3COO)_2Co$: Cobalt acetate; UT: University of Tokyo; UM: University of Massachusetts; MV: Milli Volt; UC: University of Queensland; FBC: Fosters Brewing Company; CSE: Centre for Science and Environment; MCD: Municipal Corporation of Delhi ; UE: University of Edinburgh; HCCPR: Hadley Center for Climate Prediction and Research; IPMA: Indian Paper Manufactures Association; KAISTU: KAIST University; PLA: Polylactic acid; *E: Escherichia; M: Muscodor; G: Gliocladium;* NOx: Nitrogen Oxides: MSU: Montana State University; HCs: Hydrocarbons; GHE; Green House effect; ANL: Argonne National Laboratory; PSU: Penn State University; CERI: Central Electrochemical Research Institute; SECEPU: School of Electrical and Computer Engineering of Purdue University; CLRI: Central Leather Research Institute; LU: Lehigh University; TU: Tongji University; OOU: Olabisi Onabanjo University; NEERI: National Environment Engineering Research Institute; CEPS: Common Effluent Treatment Plant.

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