ETHICS, ENERGY AND EQUITY

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The earth planet with a population of more than 6 billion, over periods of civilization in different parts of the world, has brought better quality of life to many who celebrate science & technology, management, philosophy and broad variations of capitalism and socialism. The fact remains that more than 2 billions of the living population does not have access to energy, clean water, education and healthcare. The disappointing fact is that deprived citizens which includes expecting mothers and children do not see hope and faith in the organizations in their own countries and the world systems. The population is likely to grow to about 9 billion by the end of 2050 and the climate changes are threatening to deprive the under-privileged more than those who are doing well in the world.

We find that the world is divided between optimism and disillusionment. History is demonstrative of the fact that enlightened human beings can remove disillusionment with their capacity, capability, commitment, approaches and selfless service. The nations and the world bodies require leadership of intellectuals, social scientists, scholars and believers in voice of democracy to guide the systems and societies where politicians and bureaucrats combine their sensitivity to large masses with intellectuals and professionals to have high synergy for enhancing quality of life for deprived citizens of this planet in a systematic and demonstrative manner.

This brings to focus the importance of ethics of individuals and the organizations. The current scenario also demands coherent synergy between ethical organizations to deliver equity to all citizens on this planet. Equity to me means education with healthcare and equal opportunity. Realizing a developed civilization also means creating an echo system in various parts of the world for wealth generation and management. It is clear that cost effective energy, sustainable, over centuries, for various parts of the world; with or without strong base in science & technology along with addressing the issues of global warming and sustaining and enhancing bio-diversity are the key issues. There is a need that energy, water, health, land and food are considered in a comprehensive and interlinked fashion for sustainable options to provide better quality of life to all the citizens of the plant.

Holistic approach to education which puts emphasis on learning, building skill sets, appreciation of ethics, sensitivity to all stakeholders in society and wealth generation, is key to India progressing to a developed nation. Healthcare has to be holistic and cost effective to meet the needs of a country like India, which has large population of poor persons along with growing middle class and rich population striving for best healthcare to international standards.

I wish to address energy and healthcare. The world requires increased emphasis on renewable distributed energy for all countries and enhanced contributions by nuclear energy for technology capable countries. Each country shall have to make considered decisions for a bouquet of technologies to sustain energy and environment on basis of broad principles as mentioned above. I would describe possible choice for India to meet the energy needs. India has good reservoirs of coal and hydro and these must be exploited with the best technologies, on the immediate horizon of about 50 years. Emphasis on renewable energy, namely solar and wind must be done with best of the science & technology base in the country. Bio-waste is a good option for us while biomass should be carefully considered to ensure that this option does not conflict with the food cycle for human beings, cattle and other species. Strong R&D base in nuclear energy in the country and recent indicators that India would be integrated in the world nuclear energy system for civil nuclear energy allows us to forecast a large contribution from nuclear energy in the coming 50 years. I describe below energy scenario in India, three stage nuclear power programme, fast breeder reactor programme, future of fast reactors, nuclear fuel cycle, long term energy perspective, etc.

Energy Scenario in India:

In the Indian context, the Integrated Energy Policy document of the Planning Commission, Government of India indicates that proven reserves of coal, the most abundant energy resource, at the current level of consumption can last for about 80 years. Of course, coal and lignite consumption will increase in the future and the reserves would last for a limited period. If domestic coal production continues to grow at 5 % per year, the total (including proven, indicated and inferred) extractable coal reserves will run out in around 45 years. The reserves of crude oil are merely 786 Mt. These can sustain the 2004-05 level of production for 23 years and will last only for 7 years at 2004-05 level of total consumption of the country including imports. Gas also is likely to last only about 30 years at 2004-05 consumption level. Considering the increase in production in future, it may run out even earlier.

India needs, at the very least, to increase its primary energy supply by 3 to 4 times and its electricity generation capacity / supply by 5 to 6 times of their 2003-04 levels. By 2031-32 power generation capacity must increase to nearly 800,000 MWe from the current capacity of around 130,000 MWe. Coal accounts for over 50 % of India's commercial energy consumption and about 78% of domestic coal production is dedicated to power generation. This dominance of coal in India’s energy mix is not likely to change in the next two decades. Similarly requirement of coal, the dominant fuel in India’s energy mix will need to expand to over 2 billion tonnes/annum based on domestic quality of coal. Meeting the energy challenge is of fundamental importance to India’s economic growth imperatives and its efforts to raise its level of human development. It is clear that nuclear energy has to be utilized much more intensely in the decades ahead. India has 16 nuclear reactors (installed capacity: 3900 MWe) operating and 7 more (capacity: 3380 MWe) under construction. Although nuclear power in India provides 3 % of the electricity generated in the country now, it is estimated to go up to 25 % by 2050. India has a special interest in developing Fast Breeder Reactors and use of thorium as a source of energy as it has one of the largest reserves of thorium. Japan, China, Korea and Russia also are interested in development of Fast Breeder Reactors in order to utilize the uranium resources efficiently. USA, France and many other countries are interested in using fast reactors as burners of minor actinides and long lived fission products and also to stay with and use this technology on a longer horizon for breeding and energy security.

Three Stage Nuclear Power Programme:

The total energy demand of India in 2050 is envisaged to be about 1300 GWe in terms of installed capacity. The contribution of nuclear energy has to be increased at the fastest possible pace to be able to meet about a quarter of the national electricity demand in 2050. India has rather meager reserves of uranium (61,600 t), the only naturally occurring fissile element that can be directly used in the nuclear reactor to produce energy through nuclear fission. However, nearly a third of the entire world’s thorium is available in India. Thorium is a fertile element, and needs to be first converted to a fissile material, uranium – 233, in a reactor. The strategies for large scale deployment of nuclear energy must be, and are therefore, focused towards utilisation of thorium. The large growth in nuclear power capacity can be realised only through efficient conversion of fertile materials into fissile materials and utilizing the later to produce energy. A closed nuclear fuel cycle, which involves reprocessing and recycle of fissile materials, is thus inevitable and that too, in a relatively shorter time frame than most of the other industrialized countries. Thorium reserves available in India amounts to 225,000 t with an electricity potential of 155,000 GWe-y through multiple recycling. This means that thorium can feed for 275 GWe capacity power plants for about 560 years.

The three stage nuclear power programme envisaged by Dr. Homi Bhabha consists of:

1. Pressurised heavy water reactors (PHWR) with natural uranium as fuel.
2. Fast breeder reactors (FBRs) utilizing plutonium based fuel and
3. Advanced Nuclear Power Systems with utilization of thorium.

The first stage has now matured into a robust technology with the availability factors of operating reactors touching 90 % consistently. However, the PHWR programme cannot be taken beyond a level of nearly 12,000 MWe due to limited resources of indigenous uranium. The effective utilization of the uranium resources is possible only through the Fast Breeder Reactor route by which India can achieve a power capacity of nearly 200,000 MWe for about 200 years. It was Dr. Vikram Sarabhai, who recognized inevitability and complexity of Fast Breeder Reactors in India and put into action the second stage of country's nuclear power programme. For this purpose, he created a roadmap for truly interdisciplinary research, which finally led to the establishment of the Reactor Research Centre, later renamed as Indira Gandhi Centre for Atomic Research (IGCAR). India has entered into the second stage of the programme successfully, with the design and construction of 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam.

A question that is often asked is whether India needs the fast breeder reactors, particularly when other countries have abandoned this technology presently. The countries that have abandoned fast reactors are saturated with energy generation. But a country like India wherein the per capita electricity consumption is a meager 600 kWh needs more energy. There is also undue concern of proliferation brought out in some international projections because FBR produces more plutonium than it consumes. Plutonium is a dual-use material, used in nuclear weapons as well as fuel for fast breeders. But in Indian programme, the plutonium generated in nuclear reactors is used for the new coming up power stations, mostly fast breeder reactors. It is to be emphasized that the inevitability of fast breeders in India arises both from resources utilization capacity as well as growth capability. By the use of FBRs the utilization of uranium can reach 60 to 80 % as compared to less than 1 % with Light Water Reactors (LWR) and PHWRs on once through cycle or a few present with Pu recycle. If plutonium obtained from PHWRs is straightaway used to sustain the thorium systems, then the total megawatt power capacity that can be installed would necessarily be limited and it will grow very slowly thereafter. To go to a much higher installed power capacity base at a faster pace, it is inevitable that we multiply the fissile inventory and at the present level of technologies, there is nothing better than fast breeder reactors.

Fast Breeder Reactor Programme:

The Indian fast reactor programme started with the 40 MWt / 13.2 MWe Fast Breeder Test Reactor (FBTR), commissioned in 1985 at Kalpakkam. It is the only reactor in the world, which uses the uranium-plutonium mixed carbide as driver fuel. The choice of the mixed carbide fuel for FBTR was necessitated by the technological problems anticipated in the use of high Pu content MOX fuel, and the non-availability of enriched uranium. For the first core (Mark I), a Pu/(U+Pu) ratio of 0.7 was required in the fuel. For the Mark II expanded core, the Pu/(U+Pu) ratio is 0.55. The fuel cycle of FBTR is being successfully closed, thanks to the multidisciplinary, inter-institutional research programmes, which have been pursued in a focused manner. The Mark I mixed carbide fuel has performed extremely well, reaching a burn-up of 155,000 MWd/t, without any fuel pin failure (burn-up of a fuel material is defined as the energy extracted from a given mass of the fuel: it is measured in

Megawatt {thermal} days per tonne of the fuel). Over the years, the performance of reactor systems, sodium systems, control rod drive mechanisms and other safety related and auxiliary systems of FBTR has been excellent. The purity of the coolant used in the reactor in the primary and secondary circuits was so high that there is no corrosion in the systems for years together. The four sodium pumps and their drive systems have been operating very well. Visual inspection of the reactor vessel internals has been carried out at two-year intervals and reactor internals have been found to be healthy. Presently FBTR is used as an irradiation facility for fuels and structural materials, in addition to some challenging experiments required to enhance safety of future FBRs.

As a logical follow-up of FBTR, it was decided to build a Prototype Fast Breeder Reactor (PFBR). A schematic flow sheet of PFBR is shown in Fig. 3. For PFBR, a uraniumplutonium mixed oxide (with PuO2 content of 21% in inner zone and 28% in outer zone) has been chosen as the driver fuel. Unlike FBTR, which is of loop type wherein all the primary sodium components viz. core, sodium pump and intermediate heat exchangers are connected through pipelines, PFBR is a pool type reactor where all the primary sodium components are in a single large vessel called Reactor Assembly. The reactor has 2 primary and 2 secondary loops and 4 steam generators per loop. Austenitic stainless steel type 316 LN is the major structural material for the sodium components and modified 9 Cr-1 Mo is the material for steam generator. The sodium temperatures are 820 K / 670 K for hot and cold pools respectively. The design plant life is 40 y with a potential to extend upto 60 y. The PFBR has many design features to achieve economy. A peak fuel burn-up of 100 GWd/t is targeted. The simple rectangular reactor containment building provides significant economy and construction advantages. The Government of India has accorded administrative approval and financial sanction for the construction of PFBR in Sept, 2003. A Government company, Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), was formed to implement this first commercial fast breeder reactor project. The first criticality of the reactor is scheduled in Sept, 2010. BHAVINI would be a cradle to grow into a mega organisation for delivering 500 GWe of energy through FBRs in the 21st century.

Future of Fast Reactors:

Immediately after the construction and commissioning of PFBR, a series of four 500 MWe fast breeder reactors will be constructed. It is important to reduce the cost of power to increase the competitiveness of the Indian economy, to increase the quality of life in India and to stay competitive in Indian energy market. The cost studies indicate that a series construction of four at a given one or two sites would reduce the cost by about 35 % (from Rs. 3.22 for PFBR to nearly Rs. 2.00 for future reactors). The construction time could be brought down to five years. It may be observed from Fig. 5 that the capital cost of such sodium cooled fast reactors constructed during 1970s are costlier compared to present day design. With the experience available from nearly 380 reactor-years of fast reactor operating experience available world wide, the present day capital cost are more close to that of water cooled reactors. Future plans are to go in for 1,000 MWe fast breeder reactors (beyond 2020) with improved design features and optimization at all stages. All efforts are focused on developing high burn-up and high breeding fuel, advanced structural materials and longer life of upto 60 years or more. It has also been decided that only PFBR and the next four FBRs will have the mixed oxide as the fuel and the future FBRs will use metallic alloy of U-Pu-Zr as the fuel. The decision is based on the potential of metallic alloy fuel to safely go for high breeding and high burn-up. Beyond PFBR, FBR cores would be so designed that the fuel can be switched to metallic fuels which have special significance to Indian energy scenario, for enhancing the pace of availability of nuclear energy.

To achieve the targeted growth in a sustainable manner, India has followed the philosophy of closing the fuel cycle at all stages. The power programme has thus been supported by the development of all the facets of the associated nuclear fuel cycle, with emphasis on economy, safety, minimum environmental impact, and potential for growth. The design and development activities for FBR as well as fuel cycle have the strong backup of extensive R&D inputs in the field of high temperature design, component development, thermal hydraulics, structural mechanics, materials and metallurgy, fuel chemistry, computers and instrumentation, safety and basic sciences.

Nuclear Fuel Cycle:

Closing the fuel cycle is a key element of the FBR programme, without which it is not possible to realize growth in nuclear power. For a nuclear reactor, the front end
of the fuel cycle consists of the fresh fuel fabrication plant and the back end consists of the spent fuel reprocessing plant integrated with re-fabrication and waste management. The fuel fabrication plant processes the fresh fuel to the required composition and size, fabricates the fuel pins and assembles them in the form of a fuel sub-assembly. To retain the fuel pins in the reactor for a longer time to extract more energy from the fuel, the primary limiting factor is the clad material that retains the fuel and the wrapper material, which holds the bundle of fuel pins. Hence development of advanced clad and wrapper materials for achieving high burn-up is being carried out by a combination of alloy design including innovative thermo-mechanical processing routes. Alloy D9 has been chosen as the clad for PFBR. A detailed characterization of D9 was carried out to establish the optimum amount of minor alloying elements needed for better creep, fatigue, creep fatigue interaction resistance and more important resistance to void swelling.

The PFBR fuel fabrication plant will be a part of the Integrated Fuel Cycle Facility to be set up at Kalpakkam comprising the reprocessing plant and waste management plant. The co-location concept obviates the need for transportation of plutonium rich fuel through public domain, thus avoiding the hazards during transportation. By the process of closing the fuel cycle, the high value fissile material remaining in the spent fuel is separated, processed and is recycled again to the reactor in the form of fabricated fuel pins. Minimizing the inventory of fissile material in the nuclear fuel cycle assumes importance due to cost considerations, growth of nuclear power and proliferation concerns. Considering these factors, co-locating the nuclear fuel cycle facility in the same location of the fast reactors is the preferred choice.

Reprocessing activities at IGCAR, Kalpakkam started with processing of irradiated thorium rods for separating U 233. This U 233 has been used for fabrication of mixed oxide fuel test assembly for irradiation in FBTR, before use in fast reactors. A pilot plant scale reprocessing facility has been commissioned and reprocessing of FBTR fuel has commenced successfully. Based on the experience gained in this facility, a demonstration reprocessing plant is under construction and will be commissioned in 2009 to reprocess the FBTR fuel on a continuous basis.

The reliable and trouble-free operation of the pilot plant has also given the confidence to take up the challenge of design and construction of large reprocessing plant with matching throughputs of fuel from PFBR. This fuel cycle facility will be commissioned in the year 2012, to reprocess the irradiated fuel discharged from PFBR and close the fuel cycle. This presents a unique opportunity to introduce innovations in the flow sheet for the entire facility comprising a fuel fabrication plant, a reprocessing plant and a waste management plant. The high level wastes usually generated in the reprocessing plants is a mine of wealth provided the useful elements such as Cesium and Strontium and other important elements are separated and deployed in medical and other societal applications such as irradiation of food, cancer treatment, sewage treatment etc. Also the radioactive wastes with long life can be recycled to reactors for burning. R & D in the area of development of process flow sheets to separate such elements is in progress.

Long Term Energy Perspective:

With the increasing demand for energy, India has to look for technological solutions for generation of alternate fluid fuels to hydrocarbon fuels. Most of the technologies for this application need temperatures in the range of 700°C to 900°C. In particular, generation of hydrogen from water using chemico-thermal processes needs high temperatures exceeding 800°C. Keeping this in mind, the Department of Atomic Energy has initiated programme to design and develop such a reactor system operating at high temperature. In preparation for the Third Stage, development of technologies pertaining to utilisation of thorium have been a part of the ongoing activities of the Department. Considerable thorium irradiation experience has been acquired in research reactors and we have introduced thorium in PHWRs in a limited way. With sustained efforts over the years, a small scale experience over the entire thorium fuel cycle has been obtained. An example is the KAMINI reactor, in IGCAR, the only currently operating reactor in the world, which uses U 233 as fuel. This fuel was bred, processed and fabricated indigenously. The Advanced Heavy Water Reactor (AHWR) programme provides a focal point for a time bound high intensity development in the efficient utilisation of thorium and mastering Thorium 232 – Uranium 233 bred reactors and fuel cycle technologies. In the Accelerator Driven System (ADS), high-energy proton beam generates neutrons directly through spallation reaction in a non-fertile / non-fissile element like lead. A sub-critical blanket with lesser fissile requirement will further amplify this external neutron source as well as energy. Development of such a system, which is already in progress in the DAE, offers the promise of shorter doubling time with Thoruium – Uranium 233 systems, incineration of long lived actinides and fission products and robustness to the approach towards relisation of the objective of large scale thorium utilisation.

Looking beyond fission, we have a mega energy potential in harnessing thermonuclear energy i.e. fusion energy. The International Thermonuclear Experimental Reactor (ITER) project has recently been launched to explore the possibility of harnessing fusion power. Recently India joined as full partner of this mega initiative. On present indications, successful and practical fusion power systems may become available only around 2050. There is global interest in harnessing solar energy, wind energy, energy from biomass, bio-diesel, energy from waves and from ocean thermal gradients. All these will need to be explored and utilized wherever practical and economic. In some of these areas, more research and development is warranted. The petroleum costs being high and volatile, these options, once considered uneconomic, can become cost effective in not so distant future.

Department of Atomic Energy and Society

A unique feature of Department of Atomic Energy is generating spin-offs to serve the strategic sectors, industries and society in a better way. To highlight a few, ionizing radiations are being used for sterilization of medical and food products and creating higher yield better varieties of pulses and cereals. Non-destructive examination techniques are applied for fingerprinting of ancient South Indian bronzes. A GIS based decision support system for real time application, commissioned in the Centre, is used for the real time atomospheric dispersion model and plume forecast. The resultant radiation dose due to the plume is dynamically synthesized with spatial data base of villages, road networks, schools, hospitals, population and animal husbandry. It provides complete online guidance during emergency situations and can be effectively used in other emergencies, such as chemical releases in plans, cyclones, storms, etc. There are many such applications, which need to be realized through collaborations. DAE is very keen in such collaborations.

IGCAR and Research in Healthcare

I wish to narrate three examples of applications of healthcares, in close collaborations with medical institutes.

1. A Diagnostic Tool

Infrared thermal imaging has been employed for research studies in medical diagnostic related applications. The investigations include studies on breast cancer, wound healing, arthritis, deep vein thrombosis and varicosity. Thermal imaging is the surface mapping of temperature using infrared sensors. The infrared sensor used is made of In-Sb or PtSi, having sensitivity for the spectral range of 3.6 to 5 µ. The temperature sensitivity is of the order 0.05K.

It is well known that body temperature is a useful parameter for diagnosing diseases. There is a definite correlation between body temperature and most of the diseases. The use of infrared thermal imaging for medical diagnostics related applications is based on the fact that human metabolism involves energy conversion. The change in energy dissipation pattern is expected to be the reflection of altered conditions of metabolism and helps in identification of presence of diseases like cancer or for monitoring recovery processes such as wound healing.

Studies carried out using infrared thermography indicated that the technique is effective for non-invasive diagnosis of peripheral vascular diseases, with good correlation to clinical findings. Temperature gradients are observed in the affected regions of patients with vascular disorders, which is attributed to abnormal blood flow in the affected region. The temperature in the affected regions is about 0.7 to 1^0C above the normal regions, due to sluggish blood circulation. Studies carried out also indicated that infrared thermal imaging can be employed for detection of carcinoma breast. An important finding made during these studies is that surface texture of the human body plays an important role in optimisation of the procedures for diagnostic studies using infrared thermography. Image processing and analysis technique would enhance the sensitivity for infrared thermography for medical diagnostic applications. While the studies carried out give confidence in the use of infrared thermography for medical diagnostic applications, it is essential that standardised procedures, protocols and, image processing methodologies are to be developed for successful implementation.

2. SQUID Sensors and Magnetoencephotography

Superconducting Quantum Interference Devices (acronymed as “SQUID”) are the most sensitive detectors of magnetic signals available today with a sensitivity higher than 10 femto-Tesla. This sensitivity is so high that it is possible to detect even the tiny magnetic fields associated with the physiological activities of human heart (50 pico-Tesla) or the human brain (less than 2 pico-Tesla). These sensors have a wide spectrum of applications ranging from SQUID magnetometers for laboratory research, SQUID based systems for non-destructive evaluation of materials and components, geophysical prospecting of minerals, multichannel SQUID systems for measurement of biomagnetic fields such as those associated with the activity of the neural networks in the human brain etc.

At IGCAR, we have a comprehensive programme on the micro-fabrication of SQUID sensors that involves deposition of superconducting films under Ultra-High Vacuum conditions, photolithographic processing to realize fine feature sizes in the micron range and plasma etching processes to realize device geometries. SQUID sensors developed at IGCAR are being used in a variety of applications such as SQUID magnetometer for physics research. A SQUID system based on a precision X-Y-θ scanner for non-destructive evaluation of materials is already operational and is being used for advanced research.

A SQUID based system for magnetocardiography / magnetoencephalography is also under development at IGCAR. Since the biomagnetic signals are extremely weak (pico-Tesla) compared to the ubiquitous environmental magnetic noise (nano-Tesla), a magnetically shielded room has been established at IGCAR with a shielding factor exceeding 60dB at

1Hz. This extensive shielding makes it possible to measure and characterize even the tiny magnetic signals such as those associated with human heart and human brain. We are very excited that we have been able to observe the magnetic field signal from the human heart as also the MEG signals corresponding to the alpha rhythm of human brain.

Unlike electrocardiography and electroencephalography (which requires attaching electrical leads), magnetocardiography and magnetoencephalography are non-contact measurements. Electrical signals observed are also distorted by conductivity distribution in the surrounding tissues while the magnetic signals are not so distorted since most tissues are very weakly diamagnetic. SQUID based measurement of biomagnetic fields is expected to complement the conventional diagnostic tools such as ECG and EEG. Source localization accuracies are expected to be much better in MEG compared to EEG. I request the doctors to visit our MEG facility at IGCAR to explore the possibility of collaborative work in this challenging area of research.

3. Biomaterials: Body Parts of the Future

Replacing a worn out part in a machine is no small an issue and the technology behind the replacement is nothing small either. When that's for a machine, imagine how much more it is for a living body. For example, a 40 year old women has a worn out hip joint or a 30 year old has a fractured leg leaving them immobile for the rest of their life's. In such a situation introduction of biomaterials opened up the dead-end these people came to and promised them extended years of active mobility, that's the achievement the area of biomaterials truly brought about.

During the last 90 years, man made materials and devices have been developed to the point at which they can be used successfully to replace parts of living systems in the human body. These special materials - able to function in intimate contact with living tissue, with minimal adverse reaction or rejection by the body - are called biomaterials. The earliest successful implants were bone plates, introduced in the early 1900's to stabilize bone fractures and accelerate their healing. Advances in materials engineering and surgical techniques led to blood vessel replacement experiments in the 1950s, and artificial heart valves and hip joints were under development in the 1960s.

The number of implants in use indicates their importance to health care and the economic impact of the biomaterials industry. For example, it was estimated in 1988 that 674,000 adults in the US were using 811,000 artificial hips. It was also estimated that 170,000 people worldwide received artificial heart valves in 1994. Artificial joints consist of a plastic cup made of ultrahigh molecular weight of polyethylene (UHMWPE), placed in the joint socket, and a metal (titanium or cobalt chromium alloy) or ceramic (aluminum oxide or zirconium oxide) ball affixed to a metal stem. This type of artificial joint is used to replace hip, knee, shoulder, wrist, finger, or toe joints to restore function that has been impaired as a result of arthritis or other degenerative joint diseases or trauma from sport injuries or other accidents. Artificial knee joints are implanted in patients with a diseased joints to alleviate pain and restore function. After about 10 years of use, these artificial joints often need to be replaced because of wear and fatigue-induced delamination of the polymeric component. Institute engineers are developing improved materials to extend the lifetime of orthopedic implants such as knees and hips.

Design engineers must consider the physiological loads to be placed on the implants, so they can design for sufficient structural integrity. Material choices also must take into account biocompatibility with surrounding tissues, the environment and corrosion issues, friction and wear of the articulating surfaces, and implant fixation either through osseointegration (the degree to which bone will grow next to or integrate into the implant) or bone cement. Although the wear problem is one of materials, it plays out as a biological disaster in the body. Any use of the joint, such as walking in the case of knees or hips, results in cyclic articulation of the polymer cup against the metal or ceramic ball. The average life of a total joint replacement is 8-12 years, even less in more active or younger patients.

When a man-made material is placed in the human body, tissue reacts to the implant in a variety of ways depending on the material type. Therefore, the mechanism of tissue attachment (if any) depends on the tissue response to the implant surface. Although bioactive materials would appear to be the answer to biomedical implant fixation problems, available bioactive glasses (i.e., Bioglass) are not suitable for load-bearing applications, and so are not used in orthopedic implants. This is where R&D comes in, now studies are on to look into the loading of bioactive glass onto sturdy implant materials. We at IGCAR are presently working on the preparation of nanobioactive glass powders and loading them onto titanium surfaces by anodization , this modified titanium surfaces will possess more bioactivity because of the presence of bioglass and the mechanical strength lacking in bioglass is provided for by the titanium substrate.

The science of replacing organs or parts of organs that are crucial to our existence is both exciting and potentially dangerous. Although poor heart valve designs resulting in clinical failures in the past, the current limiting factor for long-term success is the materials themselves. Two types of materials are used for artificial heart valves. "Soft" bioprosthetic materials such as denatured porcine aortic valves or bovine pericardium and "hard" man made materials used in mechanical heart valves, the most successful being pyrolytic carbon. Regular bacterial growth can often be eradicated by cleaning a surface with a disinfectant or by treating our bodies with antibiotics. However, bacteria may irreversibly adhere to surface (both man-made and natural, such as human tissue) that are surrounded by fluids. Therefore efforts are being made to make the implant material surface antibacterial. In these lines, we at IGCAR have anodized the titanium surfaces to produce anatase type of TiO2 which possesses antibacterial properties. Anodization will also increase the wear resistance of the material as well make it less prone to bacterial inhabitation.

Biomaterials research in an exciting and rapidly growing field. The process of wear of implant materials is being studied extensively using sophisticated techniques such as bioferrography, using which the wear particles are mapped and quantified so that an effective mechanism for extending the life of these structures can be deviced. Future biomaterials will incorporate biological factors (such as bone growth) drug delivery devices and maybe some self healing factors onto implant materials. Although much has been achieved, there are still numerous gaps in the area and hence call for more attention. So, biomaterial is one area, which will flourish as long as the human body exists in this universe and as long as wear and tear will lead to the need for replacement.

To summarize, adequate energy, clean environment, nutritious food, clean water, comfortable home, security in terms of law and order, freedom of speech and actions, opportunities for realizing objectives of life commensurate with individual capability, robust gross domestic product of the country, etc. are the indices of a good nation. The good quality of life has to be ensured by robust defence capacity and capability to ensure that the nation occupies a position of earned importance in the community of nations. The countrymen and the management system starting with parliaments law and order and administration system and other allied service functions in society have to be sensitive and philanthropist to work towards the good of the last citizen in the country and the world. A good nation works for enhancing capacity of the deprived nations rather than exploiting the poor nations. The world society has to be need based rather than greed based. Corruption is a disease, which is the result of poor ethics and greed. Parents, teachers, seniors and successful citizens have to take responsibility for rooting out this curse in the societies around them.

I urge the students to examine and analyse the robust heritage wheels of the east and chariots of the west without bias. The success lies in combining the best of the east with the west and discovering a paradigm shift and a balance which would enable successes for individuals and steadily increase elements of better quality of life to all the citizens of this planet.

"Abundance of virtues is satisfying and evacuation of egos is bliss"

-- *Baldev Raj*

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