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Seminar 7

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Environment – The Engineer's Human Response

Environnement – réponse humaniste de l'ingénieur

Umwelt – des Ingenieurs humane Antwort

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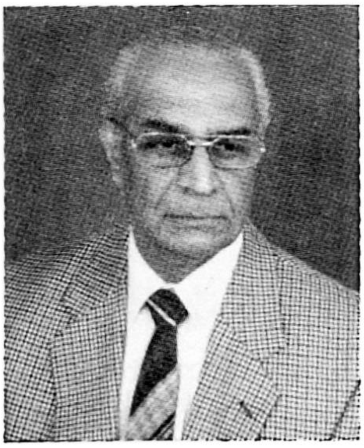

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SUMMARY

The role of the engineer has become more complex today. He is not a mere builder or one who has to accomplish his tasks within the confines of his immediate environment. Now, as never before, his role has expanded and has become global in its responsibility, coverage and application. He is now a part of the Sustainable Development on this planet, he is obliged to keep the needs of the future generations in perspective when applying his professional skills and he must help preserve the global eco-system, without delaying today's pressing needs of Man. We need to examine his new profile.

RESUME

Le rôle de l'ingénieur est devenu plus complexe aujourd'ui. Il n'est plus celui d'un simple constructeur accomplissant son devoir dans les limites strictes de son environnement immédiat. Son rôle s'est accru et est devenu global, dans sa responsabilité et son domaine d'application. Il fait partie d'un plan de développement continu et harmonieux sur cette planète. L'ingénieur doit tenir compte des besoins des générations futures, dans l'application de ses connaissances professionnelles. Il doit contribuer à maintenir l'équilibre de l'écosystème global, sans négliger les besoins de la société actuelle. Il faudrait rechercher un nouveau profil de l'ingénieur.

ZUSAMMENFASSUNG

Die Rolle des Ingenieurs ist heutzutage umfassender geworden. Er ist nicht länger ein blosser Baumeister, der seine Aufgaben im gegebenen Rahmen seiner unmittelbaren Umgebung erfüllt. Wie nie zuvor hat sich seine Rolle erweitert und ist bezüglich Verantwortung und Tragweite der Eingriffe global geworden. Er ist nun einge spannt in die Maxime des dauerhaften Wachstums dieses Planeten. Er hat sich bei der Anwendung seiner beruflichen Fähigkeiten von den Bedürfnissen zukünftiger Generationen leiten zu lassen und das weltweite Ökosystem bewahren zu helfen, ohne dabei die akuten Nöte der Menschheit zu vernachlässigen. Wir müssen dieses neue Berufsbild analysieren.

I. PREAMBLE

We live in a World which for millions of years has supported an awesome variety of plants and animals and has a human population crossing five billion today and reaching eight billion in the next 25 years. We all share and depend upon the same world, with its finite and often non-renewable resources. This implies the need for an **Ethic** common to all humankind to ensure a durable future.

We depend for survival, health and psychological well being on the physical integrity of the biosphere and the cultural continuity of our own local environment. Hence, we have a common interest in shaping an attitude that encourages more responsible use of natural resources. This is a religious imperative, links all men to a global inter-dependence, and demands unified response from individuals, communities, corporations and nations alike.

We are tenants of the World only in our own generation and hence we have no right to exhaust or deplete the finite resources of our planet. Its **'Stewardship'** by Man implies caring management, not selfish exploitation; it involves a concern for the pressent and the future and a conscious recognition that the world we manage revolves around a abiding interest stitched to man's own survival and longterm wellbeing.

Sustainable development and the aim of an acceptable quality of life for all, cannot be separated from responsible environment management-both must be integrated with all facilities of national and international bodies. "Development cannot take place upon a deteriorating environmental resource base as the environment cannot be protected when growth leaves out of account the costs of environmental destruction"(8). Therefore, environmental health has to be an important parameter in planning for economic growth.

In former years, the environment has not been a dominant subject in people's mind. Serious environmental problems are the result of both short term expediency and long term ignorance. The relationship between population, resources and environment is complex and complicated. There is inequity and inefficiency in industrialised and developing countries alike. Poverty, economic stagnation and environmental degradation interact to create tension through mindless competition for non-renewable resources, land or energy.

Some kind of **value system** is therefore inevitable; Environmental quality must ensure a balance between technical, social and economic parameters.

II. DEVELOPMENT AND GROWTH

The economists believe that to meet the basic needs of global population, without sacrificing security and stability, a five to ten fold economic expansion must take place soonest. They point out that security in an environmentally hostile world is almost an impossible task.

"Political realities in every country influence national, and hence global priorities. The affluent nations of the North, with sufficient capital to address environmental problems, now ask or cajole the struggling nations of the South to follow their lead. Yet, these nations burdened with debt and barely able to sustain the most basic needs, have a far different set of priorities. Their focus is grounded in the present rather than responding to the needs of the future. Both the ability and willingness to act on long range problems become a function of affluence"(1). Accordingly, national priorities are set within the framework of the political environment.

"Another challenge encountered on the path to a sustainable future is market economics. This type of economics historically rewards production and consumption, gauging growth-success by output of goods and services and harvesting or extraction of scarce dwindling resources. Engineers and economists would doubtless agree, that the true costs of depleting our capital of natural resources and polluting the environment are not reflected in the economic decisions that are made. The fact remains that economics and environment have been disconnected, both in our decision making process and in our institutions, and they must be merged into a new science of **'Ecological Economics'**,if sustainability is to become a reality"(1).

"Development, which is essentially change, does not necessarily involve degradation of the environment. Hence, **"Sustainable Development" may be described as a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change, are all in harmony and enhance both current and future potential to meet human needs and aspirations"**(2). There can be no question of sacrificing the environment for the sake of development. What is needed is a new era of growth, forceful and yet socially and environmentally sustainable. The ideal for developing nations would be to improve their economic growth and for the developed nations to maintain theirs. "In trying to meet the needs of the present, let us not compromise the ability of future generations to meet their own needs"(8).

Strategies for sustainable economic growth mainly concerns energy, efficiency, conservation of non-renewable resources, development of alternative energy supplies and environmental conservation. It will involve new policies of urban development, eco-layouts, housing design, transportation systems and choice of appropriate technology among others. It must not endanger the natural eco-systems that support life on earth, the atmosphere, water, soil and living beings.

It is truly stated that development is responsible for environmental stress, a result of the growing demand on scarce resources and the pollution generated by the rising living standards of the affluent. Poverty too pollutes the environment, again creating stress. The poor will often destroy their immediate environment in order to survive. They will cut down

forests and allow their livestock to overgraze grasslands. The potential effect of these changes makes poverty a major global scourge. "Thus more than development, it is the lack of it, which is seriously detrimental to the environment"(8).
Earth was created by God for man and not vice-versa. People are the ultimate resource. We must think of preserving them, today and tomorrow.

III THE ENGINEER'S NEW ROLE

"It is a known fact that an engineer solves problems and delivers solutions within the constraints of time, money and available knowledge. Yet to be agents of change, engineers must be **'proactive and creative'** and must seek to bring in environmental concerns in order to evolve and mould new options" (1). To achieve this there is a need for a professional ethic. The Engineer's orientation should change, from a **'confined thinking'** to one with a **'global mission'**, to enhance the quality of life for all humans and to preserve the quality of their environment. "Engineers thus become **'facilitators'** of sustainable development through the information that they provide, the decisions that they make and those that they influence"(1).

Once engineers were at the forefront of societal change and were looked upon as **'Leaders'**. Where the engineers have gone wrong is in the manner they have set out to improve the human lot and have assumed that this just means the greater exploitation of natural resources for the benefit of humanity. It is very necessary for the engineer to maintain a balance with ecology in the decision making process. For this reason, a human approach and the use of social science should be incorporated into the engineers skills.

The engineer as a project team leader or as a member of a team bears much of the responsibility for recommending technological alternatives. The choices that are made have a crucial impact on whether the project ends up creating problems instead of offering solutions. "Environmental aspects of all actions must have equal standing with economics and engineering as part of the project's **'go-no-go'** test"(1).

"Engineers must begin to refine existing technology options and focus on improving the resource use and minimising waste generation. Wherever possible, renewable resources should be substituted for non-renewable ones. Processes, products and technology that yield detrimental impacts must be replaced by those that do not"(1). Engineers must research new and better options for the future, through improved waste recovery processes, and must substitute environmentally safe products and processes for harmful ones, including cost-effective and timely environmental restoration technologies.

Thus as facilitators of sustainable developments, engineers must amass the skills, knowledge and information which create the path to a sustainable future. Before engineers can seriously assume such a role, it is evident, deficiencies in their environmental education must be remedied. "Whatever their discipline, the promotion of sustainable development demands that engineers cultivate an understanding of the issues, problems and especially risks and potential impacts associated with their decisions"(1). The importance of this primary need is as clear as daylight.

Paul Hofseth named us **"Pathfinders in the world of environmental technology"**. There must be fundamental changes in our approach to future global development and these changes must be initiated soon. From the Engineer's standpoint such a change requires movement towards a set of realistic, concrete steps that can be implemented at the microlevel. "The ultimate technological challenge to sustainable development represents the revolutionary leap that will be required, if the technologists are to help open the doors to a future, where all individuals can truly share in the bounties of the earth; where each society and nation can achieve more and more with less and less; where humanity can flourish in perpetuity on our planet"(1).

IV SOCIETY AND ENGINEERING

Every society practices engineering to some degree. But it is only in the last 100 - 150 years that society has really become mechanised on a large scale. A considerable degree of civilization can be secured with a minimum of engineering and though we could admiit that without engineering, civilization is impossible, it is not always of first importance.

"The Chinese who led the World in the invention of printing, the mariner's compass and gunpowder did not advance from their auspicious beginnings but evolved a civilization in which engineering had almost no place. Even their buildings, though graceful and charming, were modelled on tents and called for no great skill in their erection"(5). The Emperors used Jesuit missionaries to make fountains and clocks, but there they stopped. In due course, they paid heavily for this when a mechanised Europe attacked them and imposed its will on them.

An even more notable example of this neglect can be seen in the Greco-Roman World. The Greeks were in some respects pioneers of engineering, and the many buildings which still bear witness to Roman competence belong to the same tradition. Archimedes not only was a mathematician of incomparable genius but at times turned it to practical use, as when he invented hydro-static servomechanisms or devised engines of war to confound the Roman besiegers. Yet, despite these promising beginnings, the Greeks stopped and did no more for engineering. "The trouble with a society that does not believe in engineering or see its possibilities, is not that it is not civilized but that it is not likely to survive"(5).

In the past, the Engineer was somehow thought to be sordid and engaged in tasks below the dignity of a civilized man. "The contempt for applied mechanics displayed by Archimedes was a product of a society in which there was no shortage of cheap human labour"(5). It did not motivate the men to seek labour saving devices. This is a social fact of first importance and it is not irrelevant to modern times. The prodigious growth of engineering since the end of the 18th Century, has indeed been rendered possible by the epoch making developments like the internal combustion engine, electricity, nuclear energy, computers, etc., but this itself would never have happened, if there was no attitudinal change towards the part played by engineers in society.

"The final challenge on the path towards a sustainable future is the engineering field itself. The Engineer has always been viewed as the leading instrument in the process of social adaptation and growth. The future, therefore, will demand more of the engineering profession than has been asked in the past - demands that will require perspectives to be changed and horizons broadened"(1).

V. <u>WHY ENGINEERING?</u>

If China and Russia were more mechanised, they might not have experienced the revolution or it could have occured in a less virulent form. "Now, engineering tends to suggest that there is a cure for most evils and that the age old troubles of man such as starvation, disease, floods and the like can be surmounted by a proper use of machines"(5).

It is indeed significant that the classic case of growth without revolution should be in the USA, which has used **'Engineering'** on the greatest possible scale.

Man's struggle for existence cannot merely be maintained by exploiting natural resources but when such wealth is put to responsible use, it can certainly be made more agreeable. I would confidently assert, that life is more comfortable now for the mass of mankind than it has ever been and that this is almost due to man's increasing conquest of nature through purposely engineered machines. "A society which has become accustomed to seeing its own life improved by many engineering actions will develop a rational approach to its problems, realise that stability is something almost beyond price and be very cautious of losing it"(5). The advance of science and its practical application through engineering and chemical technology, has shown that mankind has the potential ability to achieve any standard of material wellbeing that may be desired.

"In the last few years, we have begun to ratchet our environmental concern up a few more notches to seek out opportunities to directly attack environmental problems as a purpose of the engineering effort itself and to exploit our talents in the solution of the nations present environmental problems and the prevention of future ones"(1).

In this context, can our society afford an environmentally conscious engineering technology? I believe it can and must. Contemporary shortterm thinking stands in direct contradiction to continuous sustainable development; The prodigious effort required today to correct the damage already done to our eco-system, should remind us of the consequences of our future actions.

Ofcourse, to build now in accordance with environmental considerations is more expensive than was previous construction. Nevertheless, as environmental leaders, we must invest our efforts at all levels, so that the price paid for our resources corresponds to their limited availability. This is a long term task. We must first fully learn how to build environmentally before the market forces us to do so.

Until recently, buildings were demolished and the waste thrown into landfills. Today, another approach is beginning. Instead of demolition, buildings are disassembled, materials are carefully separated and most of those recycled.

VI. ENVIRONMENT AND CIVIL ENGINEERING INDUSTRY

Each Sector within the civil engineering industry has differing environmental goals. The challenge is to establish a unified approach to provide a consistent programme for implementation. In addition to developing a state of the art approach with a view to the long term, the civil engineering industry must first acknowledge the increasing public awareness of environmental issues and must be seen to respond to environmental concerns.

The industry needs to be aware of emerging scientific findings and policy issues and to anticipate long term implications. The present approach is fragmented and not at all co-ordinated. It does not anticipate the needs for applied research or testing at a sufficiently early stage when environmental scientists have identified emerging problems.

The environmental impact of building congestion is only beginning to be understood. The need for research and testing is obvious to architects and engineers, but I also believe that manufacturers, contractors and developers have an essential role, namely how their methods and approaches may need to be adapted with an environmental emphasis.

It is, therefore, in the civil engineering industry's interest as well as its imperative care for the environment, that the industry's response should not be entirely reactive, nor solely and passively confined to satisfy statutory regulations. There is clearly a role for the industry to undertake its own initiative to provide sound information and incentive for change.

Major industrial cities often have special difficulties with slum clearances, which can result in the breakdown of communities. In new housing developments, the initial lack of both social facilities and landscaping can leave unseen many visible scars on the human habitat. New road networks, however necessary, can cause further disruption.

In smaller towns, expansion can destroy the established character and charm when supermarkets, petrol stations or office blocks of inappropriate scale replace existing historic buildings and road widening schemes out off corners and encourage traffic.

Yet our towns and cities must be prosperous to survive. All these problems and contradictions can only be resolved by engineering planners who have sensitivity, courage, vision and common sense.

The engineering profession has recognised that in the management of the environment, preventive strategies and policies are more effective and less costly than corrective measures. The application of recycling technologies and systems for utilising industrial residues are examples of the encouraging trends that are emerging.

VII EVALUATION OF ENVIRONMENTAL PARAMETERS

It is appropriate that we should start off by focussing on **'Environmental Impact Assessments'** of major engineering projects for human settlements, deforestation, land degradation, water resource depletion, flooding, mining and industrial activities; The list is not exhaustive. The use of such assessments as a process to incorporate environmental considerations is gaining increasing acceptance. Many, if not most countries, now have legislation requiring the use of EIA process before approval is given for construction and operation of large scale engineering projects.

This is very necessary, as environmental pollution caused by high population density and over development, destroys the basic safety and sanitation of the urban environment and threatens residents' lives and property.

Development generates wastes, air and noise pollution which all continuously change and damage the environment. Rapid urbanization and economic growth overshadows many historical and cultural values. Traditional structures, historical streets and cultural relics are encroached upon by tall modern buildings and noisy highways. On the other hand, rapid economic growth can also change and damage the social fabric and culture of society. In a lifestyle that stresses consumption of goods, pursuit of material gain and rapid social change, it is not easy to create an artistic, cultural environment. Preservation of cultural values in urban areas is vital to the larger urban qualilty of gracious and good living.

Space in a city is limited and property values are high. This makes urban open areas expensive. However, despite their high price tag, many residential areas have poor sunlight, inadequate air circulation and are too small to provide basic facilities like parks, green areas and walkways. Running water and sewage systems are lacking and there is often no way to build them now. In search for comparatively cheaper land, unplanned development around urban areas begin. This shifting from the city center not only hastens destruction of forests and farmlands but also makes long distance commuting a necessity and leads to traffic congestion. Often mountain slopes and swamplands are developed in such a way that rainstorms and earthquakes create landslides and floods in urban areas.

Structures must be integrated into the environment, landscape or cityscape. Heavy and brutal forms are simply offensive as they lack scale and proportion. The structure must have an effect on people and this will depend on the purpose, the situation, the type of society and on sociological relationships and initiations. People want to meet with joy in their man made environment and hence structures must bring out the qualities of buoyancy and relaxation. Now, as never before, there is need for a realisation of the holy linkage between **Man and Nature,** for his material, social and religious well-being. My ancestors adopted this as a religious doctrine and worshipped the Elements. How enlightened they were!

It is not always easy to evaluate the EIA of all the above parameters for a project's **'PASS-FAIL'** test. We have still to compile data but qualitative judgement must be exercised and engineering options proposed to the decision makers.

VIII. IMPACT OF SOME PROJECTS ON THE ENVIRONMENT

The following few cases, among many others in the world, illustrate the pragmatic and progressive interest shown by engineers, economists, politicians and a caring public, in directing the course of engineering projects.

- Nam Chon Dam - Thailand

The dam, a $400 m project proposed in 1982 and located in Thung-yal wild life sanctuary, would have led to large scale forest destruction through submergence and poaching, extinction of rare and endangered species, illegal settlement and other harmful effects, and all for a 2% contribution to Thailand's energy needs. The intense debate on the need or otherwise for the dam has resulted in the project being delayed indefinitely, in effect cancelled.

- Narmada Sagar Dam - India

The Narmada river basin programme comprises of four large and several smaller dams plus a huge canal network. They are designed to bring irrigation, electricity and drinking water to large parched areas of Gujarat.

The development has been widely criticised by both local and NGO's alike, primarily because of environmental and resettlement concerns. The Japanese decision in May 1990 to suspend financial support underscored the issues. These events helped focus attention on the problems, and several programmes for resettlement backed by legislation, specific studies and work programmes on fisheries, catchment treatment and wildlife are underway. A wary and informed public, together with the support of crusading environmentalists and engineers, has ensured protection.

- Balem - Brazilia Highway

This is a classic case of the impact of locating a 1900 km highway to open up the hinterland in the Amazon basin, without adequate prior legislation on the deforestation of the dense Amazon jungle on either side of the highway and now even farther inland. Large numbers of migrants hence encroached the area in search of land and employment. Cleared area in one sector of the highway increased 300 times in 25 years, secondary and feeder roads surfaced and the population increased from 100,000 to 2m in the zone of influence. "One traveller described this land degeneration as a 'Ghost landscape"(4). The use, or rather misuse or overuse, of the forest resource generates a backlash on other natural resources too, such as soil, water, hydropower potential, fish stocks and other natural resources. Shortcomings spill over to the Agri-sector, Public health etc. This shortsighted policy affects not only the present but future generations as well. In this context, the Engineer's immense responsibility in providing advice to the administrators is self evident. The project has now become a global concern and corrective measures are on.

- <u>The Upper Pampanga Project</u>

This is the first large scale multipurpose water resources development project in the Phillipines, and centres around the Pantabangan dam completed in 1977, to impound 3 billion cu.metres of water, and costing $ 120 million.

The project was conceived to provide irrigation facilities, power and control flood damage. Unfortunately, due to sudden population migration to the area plus improper land development leading to erosion and reservoir siltation, the objective of the project has been defeated. Soil erosion has led to loss of organic matter and nutrients, reservoir sedimentation and loss of hydropower, irrigation water etc. Inadequate government control, rural poverty, ineffective planning of land use are some of the reasons attributed to this malady. The case reflects basically lack of political will and a multilevel approach to resource management.

One should, however, not be misled to the conclusion that no environmental planning is being done despite the concerned persons being aware of its short and longterm consequences.

Take for example the case of:

<u>The Carajas Iron-ore Project</u>

Started in 1983 and costing USD 5 billion, it involves mine site development, 900 km railroad, port facilities at Sao Luis for 35 m. tons of ore export and urban infrastructure. The project was developed with close attention to the environmental impacts; these covered climatology, ecology, botany and related disciplines. The company in charge established policies in relation to forest clearing, topsoil stock piling, erosion control, vegetation regeneration, fauna protection, creation of protected reserves, related manpower training, land reclamation etc. A permanent cadre of engineers, scientists and ecologists monitor the performance and advise the management. What a responsible beginning.

Apart from this project, a great deal of thought and follow up action has been given to the construction of the Oesterschelde Storm-Surge Barrier (Netherlands), the Carlisle Bypass (U.K.), The Eurotunnel Project, the Storebelt Crossing (Denmark), The Savern Barrage (U.K.), the proposed Danube and Ganga river basin cleanup, to mention a few. Today **Environmental Studies** have become part of a major project's evaluation criteria. Still many gaps remain. Many decisions in the absence of data, are purely based on judgement and qualitative appreciation. But we have to move on, pressed by national and political compulsions.

IX. SOME GLOBAL PHENOMENA AFFECTING ENGINEERING THINKING

- The Greenhouse Effect

Carbon dioxide in the atmosphere acts like a shield trapping just sufficient quantum of solar radiation for keeping the temperature balance on earth. Fossil fuels and other man induced processes and actions are increasing the carbon dioxide content and causing the temperature on earth to increase rapidly. It is modelwise predicted that the likely doubling of carbon dioxide content **within** the next century will increase the earth's temperature in the range of 1.5^{o} C - 4.5^{o} C"(7). This will no doubt cause melting of ice and expansion of the sea both of which will affect sea level, tidal effects and ocean currents; What are the consequential effects? Submergence of estuaries, atolls and flat land areas like Bangladesh, coastal erosion, obsolesence of coastal defences and harbour structures, increased salt water penetration, change of beach life etc. Current estimates predict upto 0.65m rise in sea level at some places within the next fifty years. Engineers designing thermal, industrial, hydraulic and similar projects cannot overlook this aspect, nor the impact of pollutants caused by their design processes.

- The Ozone Phenomena

Man has been protected from high ultra violet radiation from the sun by the presence of Ozone layer. Chlorofluorocarbons (CFC) released by industry through Aerosol sprays, air conditioners, cleaning agents, refrigeration and foam, exceeding 750,000 tons by present estimate, are breaking the ozone layer and a **hole in the sky as large as Alaska** is observed recently, through satellite imagery. Ninety percent of the release arises from affluent nations and the Russian States plus China. The impact is more above 50^{o} latitude and will certainly affect whether patterns, wind velocity and direction, bird movements, besides causing acute diseases in living beings. Already citizens in some countries like Chile are warned not to go out beteen 10 AM & 3 PM, and in general people are advised to wear large hats, protect eyes with special UV absorbent glasses and cover themselves adequately from the sun during the day. Unless CFC's are checked by using alternative solutions, the outcome will be eventually catastrophic. The engineer cannot overlook this factor in his concept of structures, particularly external cladding, covered passages, etc. if solution is delayed.

- Acid Rain

The pollutants in the atmosphere mainly caused by thermal stations and industries, eg. So_x, No_x, Hydrocarbons etc., are absorbed and deposited on earth by high humidity and rain in the form of acids and cause widespread destruction to foliage, structures and human health. Winds carry the chemicals long distances and this is not a confined local phenomenon. Engineers must provide the basis for evaluating this pollution when citing new power stations and the like. In the U.K., the Government has decided to locate thermal power stations far away from cities and disperse So_x above 300 m.

- The Japanese Scenario

Japan, a nation with hardly any natural resources and rich in industry has shown the path for energy conservation and pollution control.

- Since the oil crisis in 1973, the energy consumption has been down by 30%.
- Pollution levels of So_x and No_x is the lowest among OECD countries and less than 10% of that in USA.
- Despite tripling of automobiles in the last 30 years, the concentration of No_x has remained steady during the last decade.
- 30% of the total cost of thermal power industry is invested in pollution control investment and this industry has grown phenomenally.
- Generally, the industry has become conscious of the need to control pollution and save energy in every way as a result of legislation and educational awareness.

Inspite of the additional costs to install pollution control measures, Japan's **GDP has grown eight times during the last thirty years, thus dismissing the oft-felt fear that such expenditure is counter productive.** Perhaps survival is the key motivator.

The **Montreal protocol** and the **General Environmental facility (GEF)** are movements in the right direction to control global pollution.

CONCLUSION

The Greenhouse effect, depletion of the ozone layer and perennial acid rain are all man made. Add to this the problems and consequences associated with deforestation, decreasing aquifer recharge, soil erosion and the like and we are presented with a 'Doomsday' scenario. The degradation of the planet's eco-system has enhanced the engineer's role as a 'facilitator' of change. He is no more a mere local builder. **His professional mission has indeed shifted from 'environmental concerns' to 'sustainable development'.**

Yes, our perception of what is an **'ENGINEER'** itself needs redefinition. He is now a unique and important **'citizen of the world'.** He supplements my ancestors profound vedic dictum

'Vasudaiva Kutumbakam' - 'The world is one family'. This gathering of ours from all over the world beautifully symbolises this philosophy.

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Global Climate Change: What Can Structural Engineers Do to Help?

Changement climatiques globaux: que peuvent faire les ingénieurs civils?

Globale Kilmaänderungen: Was können Bauingenieure tun?

Alain CLERC
Director
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Alain Clerc served with the Swiss federal government for 17 years. From 1989 to 1991 he was Deputy Director-General of the federal environment bureau. He joined the United Nations Environment Programme (UNEP) in 1991 as Special Advisor to the Executive Director and Head of the newly formed Information Unit on Climate Change.

SUMMARY

By emitting carbon dioxide and other so-called greenhouse gases, mankind's industrial and agricultural activities threaten to change the global climate in unprecedented ways. Scientists believe that average temperatures may increase by 3°C by the middle of the century, causing sea-levels to rise, farmlands to dry up, and much more. Structural engineers need to be aware of these potential impacts so that they design and build projects that are able to withstand the increased stresses of tomorrow's climate. They must also emphasize designs that are extremely energy-and-water efficient.

RESUME

En émettant du bioxyde de carbone et d'autres gas provoquant l'effet de serre, les activités agricoles et industrielles de nos sociétés risquent de modifier de façon jamais vue auparavant la situation climatique globale. Des scientifiques pensent que les températures moyennes pourraient augmenter de 3°C avant le milieu du siècle prochain, entraînant entre autres l'élévation du niveau des mers et la sécheresse de régions agricoles. Les ingénieurs civils doivent être conscients de ces dangers potentiels afin de concevoir et réaliser des projets capables de résister aux effets climatiques futurs. Ils doivent aussi proposer des projets extrêmement économiques du point de vue energétique et de l'utilisation de l'eau.

ZUSAMMENFASSUNG

Durch die Emission von Kohlendioxid und anderer sogenannter Treibhausgase drohen die industriellen und landwirtschaftlichen Tätigkeiten der Menschheit das Klima in noch nie dagewesener Weise zu verändern. Nach Meinung der Wissenschaftler könnten sich bis Mitte des nächsten Jahrhunderts die Durchschnittstemperaturen um 3° C erhöhen, so dass der Meeresspiegel ansteigt, Ackerland ausdörrt und anderes mehr. Dieser möglichen Auswirkungen müssen sich Bauingenieure bewusst sein, damit die Projekte, die sie planen und bauen, den zukünftigen Klimabelastungen gewachsen sind. Insbesondere ist bei der Planung auf höchste Wirschaftlichkeit im Energie-und Wasserverbrauch zu achten.

Could you imagine building a major roadway that soon buckled and crumbled into a useless pile of rubble because the frozen ground beneath it warmed up and shifted? Or a coastal highway that had to be abandoned after 10 or 20 years because the sea kept flooding it and eroding its edges? Or how about building a city in a place that became so dry that there was no longer enough water for the people living there to bathe or cook? Or where the temperatures became so hot that the building materials you used could not handle the stress?

Surely, such fiascos could only happen to companies that are careless or guilty of poor planning. But disasters of this type will be become increasingly commonplace in the decades ahead if engineers and other professionals involved in major construction projects ignore the phenomenon of global climate change.

In the past, projects intended to last for 30 to 100 years or longer could be designed to meet the constraints of the current climate. But today this is no longer the case. Scientists now have strong evidence that the climate will change in unprecedented ways over the next 50 to 100 years. They have learned that mankind's industrial and agricultural activities are emitting carbon dioxide and other so-called greenhouse gases that are changing the way the atmosphere absorbs the sun's energy. This threatens to upset our climate's delicate balance faster and more dramatically than ever before in human history. If no action is taken to reduce greenhouse gas emissions, many of the world's societies and eco-systems may suffer devastating damage.

Is this just another exaggerated disaster scenario designed by the press and environmentalists to frighten people? No, it is not. As director of the Information Unit on Climate Change, it has been my privilege to meet and to work with some of the leading researchers in this field. Scientists are not hysterical types. In fact, they are extremely conservative, and they are used to having their work judged by the rigorous and demanding standards of their scientific colleagues. They do not pander to environmental activists or to other politically motivated groups.

Higher temperatures and sea-levels

Scientists believe that one of the main effects of mankind's emissions of carbon dioxide and other greenhouse gases will be global warming. Assuming that no action is taken to reduce emissions, computer models of the earth's climate predict that global average surface temperatures will rise by 1-3 degrees centigrade by the year 2030. This is larger and faster than any such change over the past 10,000 years. There is some evidence that this warming has already begun. Further global warming would shift climate belts towards the poles. For example, according to the global warming scenarios predicted by many models, the climate of Finland will come to resemble that of present-day northern Germany, and Iceland will experience conditions similar to Scotland's. It is less clear how warmer, semi-arid regions will be affected, but the expectation is that higher temperatures will cause more droughts and expanding desertification in many developing countries.

Clearly, rising temperatures will have a direct impact on infrastructure such as roads, buildings, and dams. For example, global warming would lead to a general melting of permafrost in Alpine and northern tundra regions, making the ground less stable for existing transport and building infrastructure. Elsewhere, higher summer temperatures would lead to increased heat stress for people as well as for physical infrastructure. In addition to higher average temperatures, global warming would cause an increased frequency of extreme events, such as heat waves. For example, the city of Washington DC currently experiences 36 days per year when the temperature exceeds 90° Fahrenheit and one day when it exceeds 100° Fahrenheit, or 33 and 38 degrees Celsius respectively. But a study by a NASA scientist concluded that if atmospheric concentrations of carbon dioxide double, then the number of days above 90°F would increase to 87, and the number of days above 100°F would increase to 12. In other words, the temperature for most of the summer would exceed 90°F, with two weeks above 100°F. How much of the existing infrastructure has been built to withstand years of such stress?

Perhaps the most dramatic result of higher temperatures will be a rise in sea-levels. Global warming would cause the sea to rise in two ways: through thermal expansion of ocean water, and by discharges of fresh water from continental ice caps and mountain glaciers. Many scientists believe that the global mean sea-level has already risen by 1-2 centimetres during the past century. Climate change is expected to cause a further rise of some 20 centimetres by the year 2030 and 65 centimetres by the year 2100. Some forecasts call for even higher sea-level rises.

Higher sea-levels would cause immense damage. Perhaps 20 centimetres doesn't seem like much, just as a 1 or 2 degree temperature rise may not sound so dramatic. But a rise in sea-level would create irreversible problems for millions of people. Some of the nations that are most at risk are small islands in the Pacific, the Indian Ocean, and the Caribbean -- some of which may have to be completely abandoned -- as well as Bangladesh, Egypt, Gambia, India, Indonesia, Mozambique, the Netherlands, Pakistan, Senegal, Surinam, Thailand, and Vietnam. Other high-risk areas are estuaries and low-lying cities and provinces such as Sydney, Shanghai, and southern Florida.

The direct costs of rising seas would amount to hundreds of billions of US Dollars. One leading economist (William Nordhaus) has calculated that protecting coastlines from a 70-centimetre sea-rise by building dikes and other barriers would cost 618 billion dollars in terms of 1981 dollars during the next 100 years. The indirect and non-market costs of a sea-level rise would dramatically increase this figure. Indirect costs would include the loss of coastal industries such as fishing and tourism, and of buildings and other infrastructure. The costs of resettling populations and of rebuilding would also have to be considered, as would non-market costs such as social dislocation, the intrusion of salt-water into estuaries and aquifers, and the loss of biologically rich eco-systems. Economists are now trying to refine new methodologies for measuring these indirect and non-market implications.

Worsening storms and droughts

Most accounts of climate change have emphasized the outlook for hotter temperatures and higher sea-levels. But in fact these two impacts may not be the most important. Other changes, such as growing storm activity and increasing droughts and water shortages, may wreak even more damage. Scientists believe that climate change may cause hurricanes and tropical storms to increase in intensity and perhaps in frequency. Meanwhile, expanding droughts and dryness would put greater pressure on global freshwater resources. The large water requirements of households, industry, and agriculture are already creating problems in areas where water is scarce. Conflicts over water resources are likely to worsen, particularly in regions with rapid population growth.

Climate change will make water resources even more vulnerable than they are now, particularly in arid and semi-arid countries. If climate change reduces precipitation in a region, the freshwater storage reserves, primarily in the form of groundwater, will steadily shrink. An increase in extreme events such as droughts and floods, or even more modest variations in precipitation from year to year, can also seriously disrupt water supplies. Lowered fresh-water levels would require major adjustments by urban settlements located on the shores of rivers and lakes and would have an enormous impact on engineering projects -- not only on dams and other water-related projects, but on any building or project that consumes water.

These dramatic impacts -- warmer temperatures, higher sea-levels, droughts, and storms -- would clearly have social and economic repercussions. Disputes over limited or diminishing resources such as water and arable land would proliferate, both between individual countries and within them. This would put societies under greater stress. Where adjustments could not be made quickly enough, social unrest, protest movements, and political instability would probably increase. In already-fragile societies, the stress of climate change could lead to either complete social breakdown or to more authoritarian rule. If climate change has its predicted impacts, many developing countries may lack the necessary resources for protecting themselves. Social upheaval and economic crisis would strongly affect the project needs of developing countries as well as their ability to maintain and to pay for these projects.

What can be done?

So much for the likely consequences of climate change. Now, what can you, as concerned citizens and as engineering professionals, do to help minimize climate change and its impacts? Allow me to make the following proposals:

First and most importantly, reduce the use of fossil fuels by the projects that you construct. Energy from fossil fuels is believed to be responsible for about one-half of man-made climate change. In the year 1985 alone, the combustion of oil, gas, and coal released some 5.3 billion tons of carbon dioxide into the atmosphere. At current rates of per-capita emissions and world population growth, CO_2 emissions will more than double in many regions by the year 2025. To prevent this, we must make technical improvements to the composition of fossil fuels, increase our energy efficiency, and replace fossil fuels with solar energy and other energy sources that do not emit greenhouse gases. Governments may soon coax industry to reduce its fossil-fuel emissions by imposing national emissions targets, carbon taxes, and tradable emissions permits schemes. Most OECD member states have set national targets for stabilizing or reducing their emissions of greenhouse gases. In 1990, the Council of the European Communities adopted a policy that provides for stabilizing the emissions of carbon dioxide at 1990 levels by the year 2000. However, unless much more drastic efforts are made, Europe's emissions seem set to *rise* by 11%.

As shown by the dramatic recent evidence that an enormous ozone hole may be opening up over the Northern hemisphere this spring, sudden and frightening evidence that confirms climate change could come at any time. This would result in growing pressure on you to make rapid improvements in the energy-efficiency of your designs. In addition to tackling this technological challenge, you may want to support efforts to reduce emissions via reliance on carbon taxes, which would probably be the most economically efficient way to achieve this goal.

Your second contribution can be to radically raise the water efficiency of all your project designs. For example, many areas of India, the site of your last Congress, already experience dry periods that force people to make careful use of water resources. Improved water management will prove even more essential if climate change reduces the monsoons or regular rainfall. Other important steps you could take would be to support government efforts to sensitize people to the problems of water wastage and to introduce policies or taxes to constrain demand. Finally, you could support the creation of a worldwide inventory of national water resources to support water-use planning in the event that climate change has its predicted effects on water supplies.

The third way you can contribute is by planning for rising sea-levels. Don't build inappropriate projects in vulnerable areas. Meanwhile, support the efforts of coastal nations to discourage unsustainable development in coastal areas and to implement emergency preparedness and response mechanisms. Most of these measures would have numerous benefits for these countries and would be justified even if sea-levels do not rise as much as predicted. Don't forget that in addition to the havoc caused by rising sea-levels, your designs may also have to cope with other stresses, including increasing storms, droughts, and floods.

Fourth, do not allow your projects to lead to a net loss of forest cover. Although industry and energy are the leading causes of climate change, the over-exploitation of ecological resources also produces greenhouse gases. Deforestation, which over the past 25 years has lead to the loss of more than 15% of the tree cover in some countries, has a number of adverse effects on the climate. Most importantly, it releases into the atmosphere carbon that was previously sequestered in trunks and leaves, either directly through burning, or indirectly through decomposition. Deforestation also reduces evapotranspiration, particularly in rain-forests, which upsets the atmospheric water cycle on both a small and a large scale. justifications for massive deforestation in the first place.

Reforesting the earth will be critical to reducing the amount of carbon dioxide in the atmosphere. Growing 370 million hectares of new forest, an area equal to about one-half of the Amazon Basin, would absorb 17% of current annual fossil-fuel emissions of carbon dioxide. The problem is that, with a growing world population putting ever greater pressure on land resources, it is becoming increasingly difficult to set aside large tracts of forest. We must all make special efforts, then, to reverse the current trend of cutting down more trees than we plant.

So far I have outlined several ways that engineering professionals can help people to cope better with the impacts of climate change. But there is much more you can do as well. You can transfer technology to developing countries to enable them to participate in solving what is truly a global, and not merely a national problem. You can also, as other industries and professions have done, become involved in the negotiation process for a legally binding global treaty on climate change. Whether climate change proceeds quickly as some scientists believe it will or at a more moderate pace, a delay in adopting global policies to reduce greenhouse gas emissions could lead to significantly more global warming. The negotiation process began in 1990, when the United Nations established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC) to draft a legally binding climate treaty. The draft convention is to be ready for signature at the UN Conference on Environment and Development (UNCED) in June 1992. Even if we act now, it is probably too late to avoid some degree of climate change, but if governments can agree on policies to reduce greenhouse gas emissions, negative effects such as higher temperatures could be greatly reduced.

By recognizing the scientific evidence on climate change, then, the engineering profession can build infrastructure that will be suitable to tomorrow's climate and that will not prove obsolete before its time. It can also help to reduce the negative impact of human activities on the global climate, and help people to adapt to those changes that we are unable to prevent. I hope you will accept this challenge.

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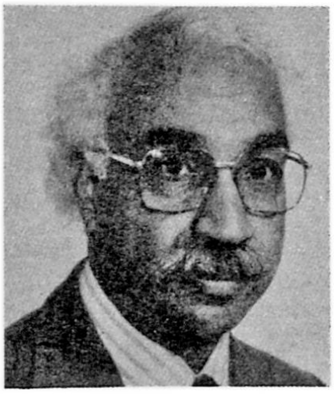
Climate Change: What Can We Do About it

Changements climatiques: que faire?

Klimaveränderung – was können wir unternehmen?

N. SUNDARARAMAN
Secretary
Intergov Panel on Climate Change
Geneva, Switzerland



N. Sundararaman, born 1937, got his Ph.D. in meteorology from the University of California at Los Angeles, USA. After working as a professor for some time, he became the Manager of the Air Quality Division of the US Federal Aviation Administration. His work encompasses ozone depletion and climate change.

SUMMARY

Given that the atmospheric concentrations of the greenhouse gases (GHGs) ar likely to continue for some time to come, some global warming appears inevitable. While international efforts are underway to eventually stabilize GHG concentrations, adaptation should become an important part of the response options. Bridge and structural engineers have a vital role to play here.

RESUME

Une mise en garde globale devient inévitable, puisque les concentrations atmosphériques de gaz, combinées avec l'effet de serre, risquent de se poursuivre dans les années à venir. Bien que des efforts soient en cours à l'échelon international pour stabiliser ces concentrations de gaz, il est nécessaire de s'adapter à la situation actuelle. Les ingénieurs civils ont un rôle vital à jouer dans ce domaine.

ZUSAMMENFASSUNG

Bei den gegebenen Konzentrationen von Treibhausgasen in der Atmosphäre, mit der wir wohl noch eine ganze Weile werden leben müssen, scheint eine globale Erwärmung unvermeidlich. Trotz gegenwärtiger, internationaler Anstrengungen, ihre Konzentration langfristig unter Kontrolle zu bringen, sollte eine Anpassung an die Klimaveränderung zur wichtigen Handlungsoption werden. Brücken und Hochbauingenieuren kommt dabei eine wichtige Rolle zu.

1. INTRODUCTION

1.1 The views expressed in this paper are my own and do not in any way reflect the official positions of the Intergovernmental Panel on Climate Change (IPCC) or of its sponsoring organizations, viz., the World Meteorological Organization and the United Nations Environment Programme. This paper is based on the findings of the IPCC First Assessment Report [1] and the 1992 IPCC Supplement [2].

1.2 It may be noted that SI units are not used this paper.

2. THE GREENHOUSE EFFECT - SCIENTIFIC EVIDENCE

2.1 There is ample scientific evidence that the greenhouse effect is valid:

- From observations of the atmospheric compositions of the planets Mars and Venus, their surface temperatures can be deduced using the greenhouse theory. The calculated temperatures compare very well with observed values as may seen from the table below.

	Main GHGs	Calculated temperatures, °C		Observed temperatures, °C
		Without GHE	With GHE	
VENUS	>90% CO_2	-46	523	477
MARS	>80% CO_2	-57	10	-47

Note: GHG - greenhouse gases; GHE - greenhouse effect.

Table 1 Planetary temperatures - comparison of observations and calculations using greenhouse theory

- Atmospheric concentrations of carbon dioxide and methane over the past 160,000 years can be deduced from ice cores; corresponding temperature values can be obtained from deuterium data. The concentrations for both gases correlate exceptionally well with the temperatures as can be seen from figures 1 and 2 below.

3. CALCULATIONS OF CLIMATE CHANGE

3.1 The so-called coupled general circulation models (CGCMs) are used to calculate changes in temperature and other climate variables (precipitation, soil moisture etc.). The models include atmospheric and oceanic processes, some of them parameterized. The parameterizations constantly undergo evaluation and improvement. Nevertheless, the models are the only tools available to project future climatic states (in this paper, only changes in temperature will be discussed). About half a dozen of these models are in existence today.

3.2 The time evolution of the future atmospheric concentrations of the greenhouse gases is a very critical input to the models.

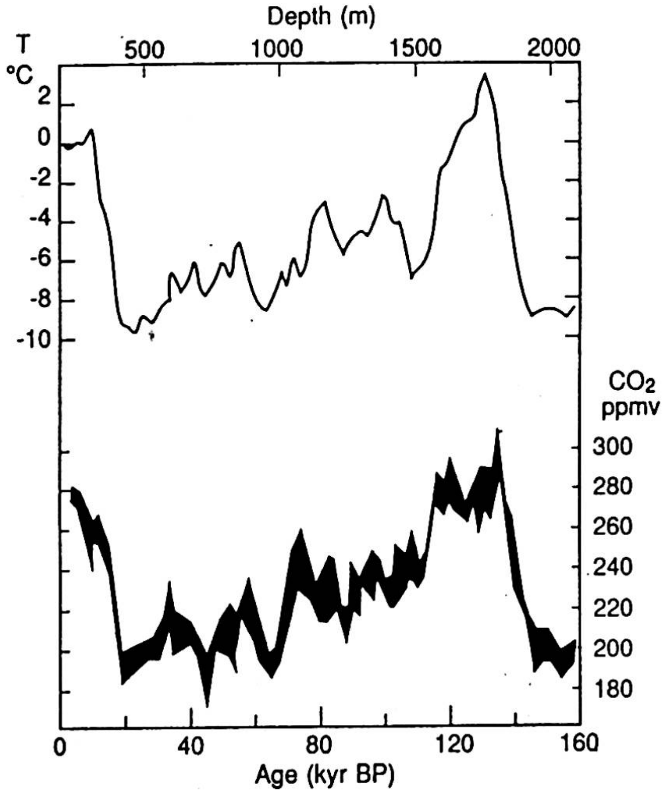


Figure 1 CO_2 concentrations (bottom) and estimated temperatures (top) in the last 160,000 years

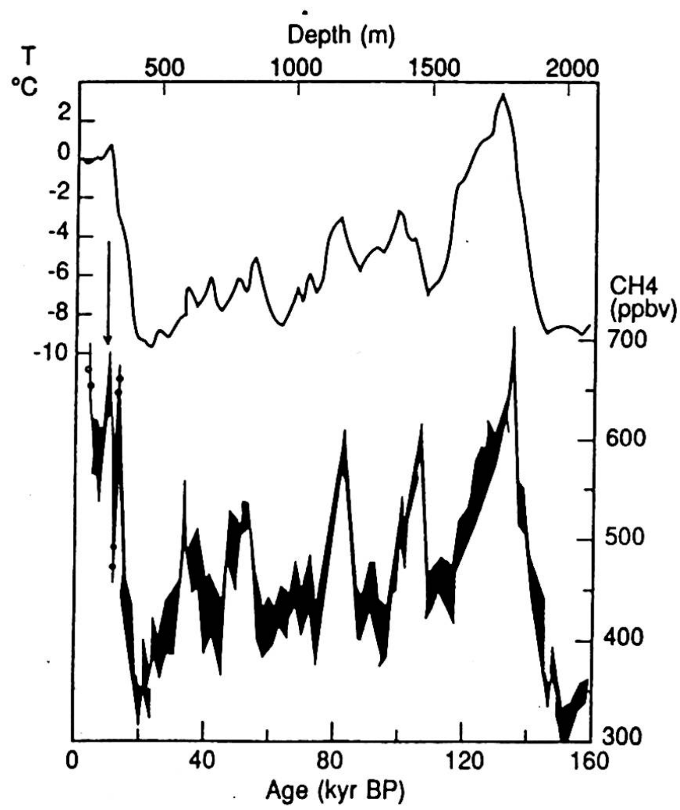


Figure 2 Methane concentrations (bottom) and estimated temperatures (top) in the last 160,000 years

Such evolution is very hard to forecast since many socio-economic factors such as rates of economic growth and the means to satisfy the latter's energy and other needs would influence future emissions of the greenhouse gases. In addition, a detailed knowledge of the chemical and other sinks of the gases is needed in order to calculate the amounts that would remain in the atmosphere. The task becomes mammoth and fraught with large uncertainties when time horizons of a century or more - typical of global warming due to greenhouse gases - are considered.

3.3 Thus, assumptions have to be made about future emissions of the greenhouse gases. Such assumptions are known as emissions scenarios; they are more in the nature of working hypotheses and are not predictions of future emissions. In this sense, then, there are no predictions of future climate. (This, however, is not to say that climate is not predictable - quite the contrary.)

3.4 The IPCC considered 4 emissions scenarios in its first assessment [1] to illustrate the effects of different response options. One of them (the Business-as-Usual scenario or Scenario A) assumes that no action is taken to stabilize the concentrations of the greenhouse gases. The others correspond to an equivalent doubling of atmospheric CO_2 over the pre-industrial value (of 280 parts per million by volume) assumed to occur in the years 2030, 2060 and 2090 respectively. (The radiative effect of all greenhouse gases is often expressed in terms of the concentrations of CO_2 that would be required to produce the same effect - this is the concept of "equivalent CO_2".) They are all shown in figure 3.

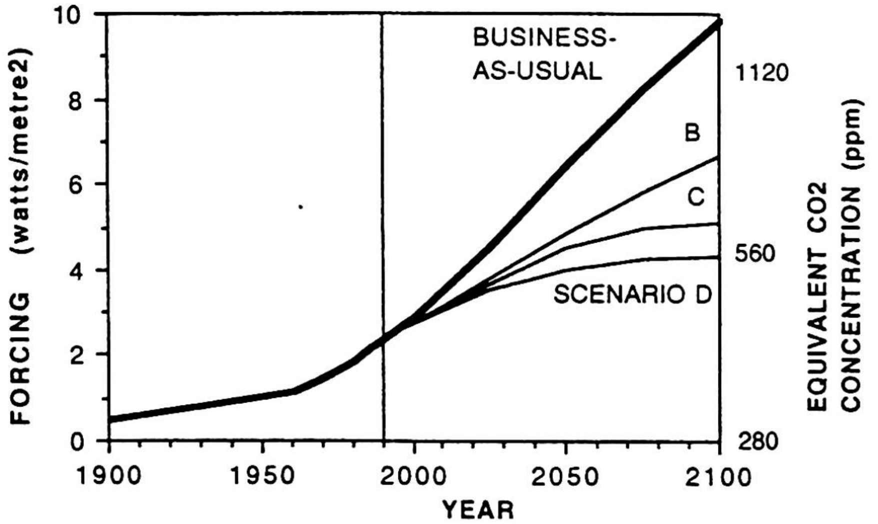


Figure 3 IPCC Emissions scenarios

3.5 The IPCC calculations of increases in the global average temperatures corresponding to the Business-as-Usual scenario is given in figure 4. The range of estimates given, from high to low, indicates the uncertainty in the calculations. The uncertainties arise from feedback mechanisms (such as, for example, of the shrinking ice and snow leading to reduced reflection back to space of incoming solar radiation). The calculations of temperature increases as well as increases in mean sea level rise for 3 of the 4 scenarios are given in table 2.

4. THE CONCEPT OF THE "REALISED" CLIMATE CHANGE

4.1 In figure 4, it may be noticed, the ordinate is labelled "realised temperature rise". This is an important concept and has some implications for responding to global warming. It is best illustrated by the following example.

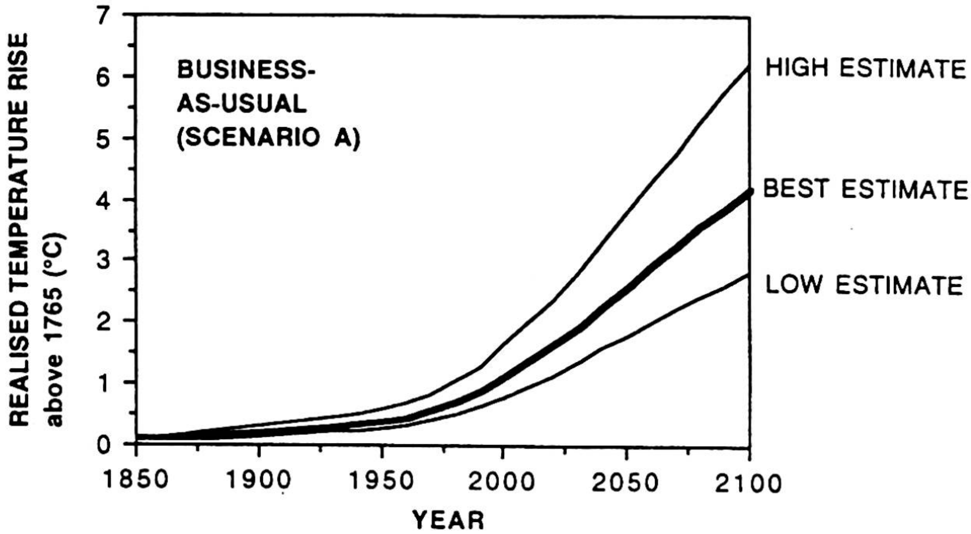


Figure 4 Calculated increase in the global mean temperature for the Business-as-Usual emissions scenario

Emissions scenario	Rate of increase of temperature °C/decade	Rate of increase of sea level cm/decade
Business-as-Usual	0.3 (0.2-0.5)	6 (3-10)
Scenario B	0.2	4
Scenario C	0.1	3.5

Table 2 Calculated rates of increase in the global average temperature and mean sea level for a few IPCC emissions scenarios (The numbers in parentheses indicate the uncertainty range)

4.2 Barring unusual weather phenomena, the daily maximum in the temperature usually occurs around 2 or 3 o'clock in the afternoon. The cause of the temperature is the forcing by the sun. The forcing maximum is at local noon but the maximum in temperature is only observed a few hours later. That is, the "commitment" to maximum temperature is made at noon but at noon the "realised" temperature is less than the maximum, i.e., that which is already "committed" for happening. The reason of course is the time lag in the response of earth-atmosphere to the solar forcing.

4.3 The same concept applies to global warming. In the case of the daily temperatures, the lag is of the order of an hour or so. In the climate case, the lag can be several decades to centuries (because of the huge heat capacity of the oceans).

4.4 Thus, as long as greenhouse gases continue to increase in the atmosphere - and at present all observations indicate monotonic increases in CO_2, methane, nitrous oxide, the chlorofluorocarbons, all of them with greenhouse properties - the temperatures would be less than what would be "committed" to. This is more readily understood in the case of sea level rise.

5. IMPORTANCE OF ADAPTATION AS RESPONSE TO CLIMATE CHANGE

5.1 Given the nature of the "realised" effects, a certain amount of warming (and associated impacts) would appear inevitable. It would be quite a while before the concentrations of the greenhouse gases can be stabilized, assuming that such a goal is aimed for and steadily pursued. In the meanwhile, the greenhouse gases emissions would continue, increasing with time the greenhouse forcing.

5.2 Thus, it would be prudent to include adaptation in the measures to respond to climate change. Adaptation should be deemed an important part - perhaps the major part in the next two or three decades - of the available options. This has to be done at primarily the national level. But in order to adapt, and adapt at least cost (assistance in this regard to the developing countries is another matter altogether and is not discussed here), better knowledge of the impacts of climate warming on the physical and socio-economic systems would be necessary. The bridge and structural engineers have a vital role to play in this effort.

6. CONCLUSION

6.1 It is an observational fact that greenhouse gases are increasing in their atmospheric concentrations today. The trend is likely to continue for some time to come (given, for example, that the time scale of restructuring energy systems is a few decades). And, at any given time, the temperature increase would be always less than what is committed for. Thus, adaptation becomes an important option to manage climate change. This requires a good knowledge of the impacts of climate change on the physical and socio-economic systems. The IABSE could contribute constructively in this effort.

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Society-Engineer-Environment: Perspective of Practising Consultants

Société – ingénieur – environnement: point de vue de l'ingénieur-conseil

Gesellschaft, Ingenieur und Umwelt: aus der Sicht eines Beratungsbüros

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SUMMARY

In this article, an attempt has been made to draw up the present perspective of the interrelationship of society-engineer-environment from the point of view of practising consultancy agencies in the field of environmental management. The counteractive strategies, social role of engineers, environmental screening approaches for vulnerable projects, the concepts of sustainability and its quantifiable assessment possibilities, have been discussed.

RESUME

L'article exprime le point de vue d'un ingénieur-conseil spécialisé dans la gestion de l'environnement, sur l'évolution possible de la relation entre la société, l'ingénieur et l'environnement. Il traite de stratégies communes, du rôle social de l'ingénieur, des approches écologiques de projets sensibles, des concepts de développement continu et harmonieux, et de l'évaluation de diverses alternatives.

ZUSAMMENFASSUNG

Der Beitrag zeichnet die gegenwärtige Perspektive der Dreiecksbeziehung zwischen Gesellschaft, Ingenieur und Umwelt aus der Sicht eines Beratungsbüros mit Tätigkeit im Umweltmanagement. Er behandelt Eindämmungsstrategien, die soziale Rolle des Ingenieurs, Umweltveträglichkeitsprüfungen für sensible Projekte, die Konzepte dauerhaften Wachstums und Möglichkeiten seiner quantitativen Beurteilung.

INTRODUCTION

In today's world, the interrelationship of society, engineer and environment can be viewed from many angles. One such perspective is that of practising consultants engaged in project implementation. This perspective, perhaps, develops from the following definitions of these building blocks:

Society : A structured and collective system of human organisation for large scale community living that furnishes protection, continuity, security and an identity.

Engineer : A person versed in the art of science of making practical application of knowledge in the design and construction of bridges, buildings, mines, plants, machinery and the like.

Environment: The aggregate of surrounding things, conditions and influences.

The above characteristics of 'Society', 'engineer' or 'environment' introduce certain functional demands in them. An engineer turns out to be the initiator of industrialisation which in turn leads to urbanisation of the society with increased population. This in turn, puts pressure on the local environment and ecosystem of the planet earth.

The above interrelationship is best represented with a system that can be called as a "model of concentric subservience" (Fig.1), in which the engineer is at the core with concentric envelops of the society, environment and the planet Earth. The engineer's efforts of disturbing the nature lead to societal problems which in turn, result in the disturbance of ecosystems in the local environment. All these degradational effects are supposed to be solely contained by the planet Earth with its self-sustaining natural systems.

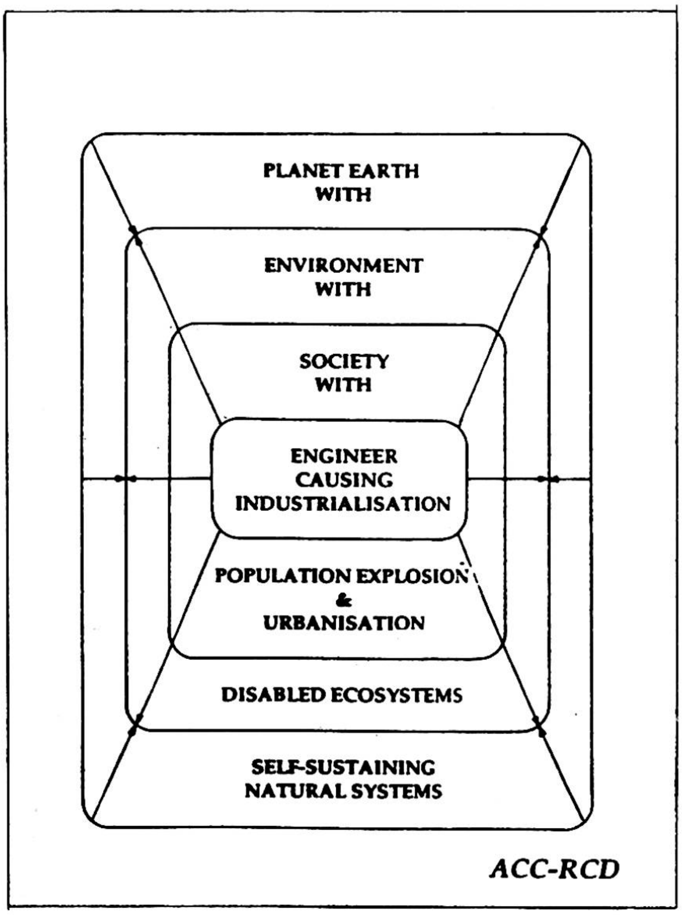

Fig 1. Model of concentric subservience

PRINCIPLES OF SELF SUSTAINENCE

Needless to mention that when there is no natural or man-made perturbation, the biosphere turns out to be an excellent autosustainable and self-generating system with only the solar energy as the external input (Fig.2) [1]. But the total elimination of natural or man-made perturbations is not possible in most circumstances. Even then, as long as the perturbations are within limits, the self-sustainance of cyclic phenomena can be restored as displayed in Fig.3.[2] which depicts man-made and

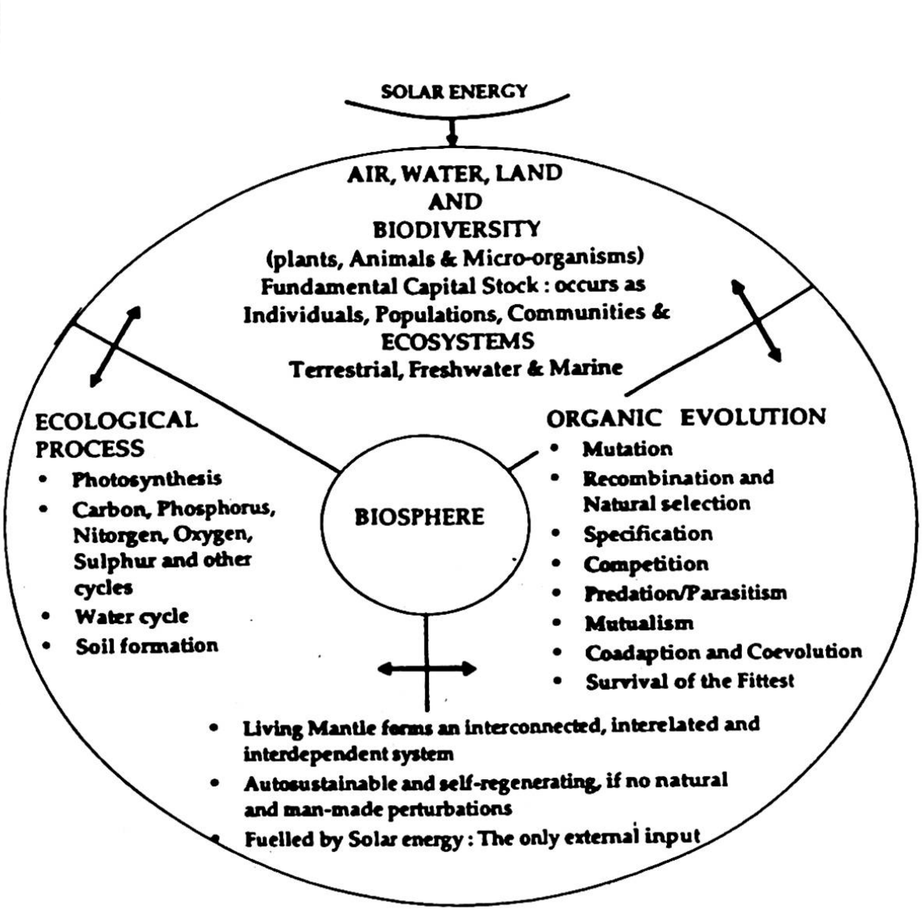

Fig. 2 Interactive components of Biosphere

ACC-RCD

natural contributions to the natural carbon cycle through fossil-fuel burning and volcanic eruptions respectively.

If one attempts to critically study such phenomena in nature, one finds that the self-sustainance of natural systems is governed by the three basic principles of sustainability, which are as follows:

(i) Outputs: Waste emissions from a project should be within the assimilative capacity of a local environment to absorb without any unacceptable degradation.

(ii) Renewable inputs: These should be within the regenerative capacity of the natural system that generates them.

(iii) Non-renewable inputs: The depletion rates should be equal to the rate at which renewable substitutes are developed by human invention and investment.

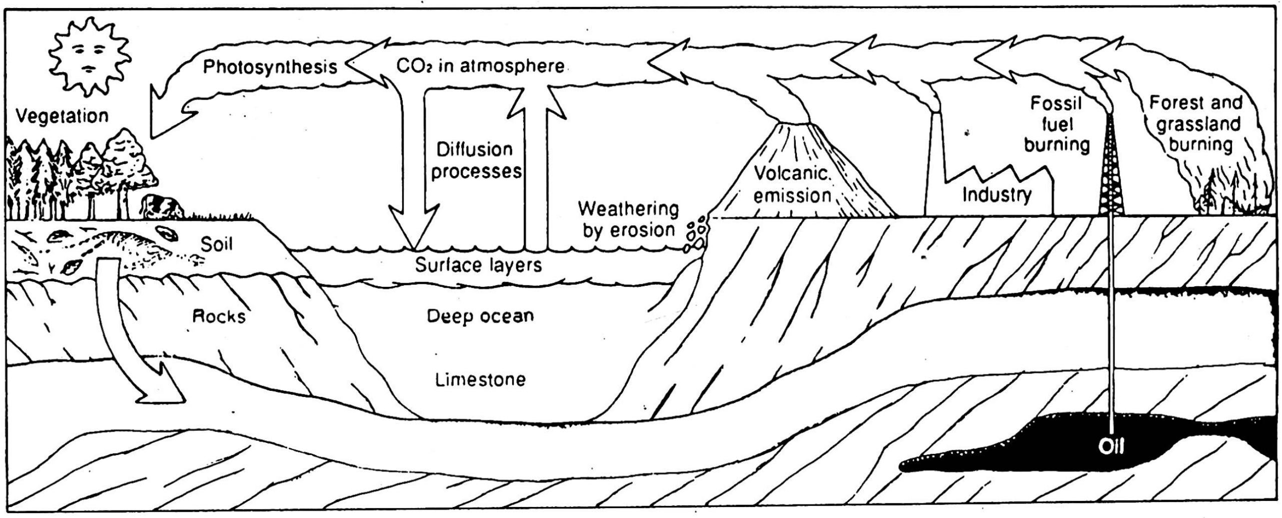

Fig.3 Carbon Cycle at global level

Unfortunately, the above principles of sustainability in real-life situations are difficult to be realised or implemented due to several constraints, two of which need special mention - fallibility of engineers and intrinsic conflicts in managing our environment. These aspects are expounded below:

CONSTRAINTS OF SUSTAINABILITY

Fallibility of Engineers

If one tries to track down the engineering catastrophies in historical times, one may find countless examples of failures, some of which are due to human frailties and some due to human faults. Let us consider the following examples:

* Failure of Tacoma Narrows Bridge in U.K. in 1836, in which case the disastrous effects of a natural phenomenon like wind excitation was, perhaps, beyond the comprehension of designers then.

* Collapse of Coledale Embankment in New South Wales in 1988, in which the proneness of the land to subsidence could not be gauged.

* Failure of challenger shuttle in 1986 which is ultimately traced to neglectof inspection of components.

All these examples reveal the concealed uncertainly in engineering profession which has been aptly defined in the context of structural engineering as follows [3]: "Structural engineering is the art of modelling materials we do not wholly understand into shapes, we cannot precisely analyse so as to withstand forces, we cannot properly assess in such a way that the public at large has no reason to suspect the extent of our ignorance".

Conflicts in Environmental Management

The above weakness of engineering profession gets aggravated manifolds with several conflicting issues that emerge in managing our environment. The more critical issues can be summarised as follows:

(a) While the growth of human population and human activity is explosive in nature, the counteractive approaches are adaptive and slow.

(b) While the environmental changes are science-induced, our understanding of such science is still incomplete.

(c) While in the management of environment there is a strong superimposed effect of economic and social processes, our understanding of such additional impact is grossly inadequate.

(d) While the economic development is a resource-use concept, the environmental protection is a resource conservation and management concept.

ENVIRONMENTAL IMPACTS OF HUMAN ACTIVITIES

In such conflicting situations aided and abetted by human frailties, the environmental impacts have been enoumous due to human activities. The decline of ancient civilisations in the plains of the Euphrates-Tigris, the Nile, the Indus, the Ganges, etc. was believed to be due to indiscriminate deforestation, decimation of animal life, etc.

With increasing tempo of industrialization in the 18th century the impacts of human activities on our environment have been significantly higher than what was, perhaps, experienced in the prehistoric times. An idea of the magnitude of such impacts can be had from Table 1 [4].

Table 1 - ENVIRONMENTAL IMPACTS OF HUMAN ACTIVITIES SINCE BEGINNING OF THE 18TH CENTURY

- POPULATION INCREASED BY A FACTOR OF EIGHT
- LIFE EXPECTANCY DOUBLED
- INTERNATIONAL TRADE OF MANUFACTURED GOODS INCREASED BY A FACTOR OF EIGHT HUNDRED
- LOSS OF SIX MILLION SQ.KM. OF FORESTS
- SEDIMENT LOADS IN RIVER SYSTEMS INCREASED THREEFOLD
- CARBON FLOW TO SEA ESTIMATED BETWEEN ONE TO TWO BILLION TONNES A YEAR
- WITHDRAWAL OF WATER FROM THE HYDROLOGICAL CYCLE INCREASED TO 3600 CUBIC KILOMETRES PER YEAR
- METHANE CONCENTRATION IN ATMOSPHERE DOUBLED
- CARBON DIOXIDE CONCENTRATION INCREASED BY 25%
- MORE THAN 70,000 CHEMICALS SYSTHESISED
- EMISSION OF IMPORTANT TOXIC ELEMENTS (TIMES MORE THAN THE NATURAL FLOWS)
  - — Pb (18), Cd (5)_, Zn (3)
  - — A, Hg, Ni & V (Each 2)
  - — S & N (≈)
- CFC & DDT ESTABLISHED AS MAJOR ENEMIES OF ENVIRONMENT

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The resultant environmental concerns are summarised in Table 2.

Table 2 - RESULTANT ENVIRONMENTAL CONCERNS

- *RURAL-URBAN DRIFT LEADING TO ENORMOUS PRESSURE ON WATER SUPPLIES AND WASTE DISPOSAL*
- *EROSION AND SEDIMENTATION CAUSING PERENNIAL AND RECURRING FLOODS*
- *POLLUTING EMISSIONS (PARTICULATE, LIQUID AND GASEOUS) LEADING TO CLIMATIC CHANGES/GREENHOUSE EFFECTS*
- *ACID RAINS AND PHOTOCHEMICAL SMOG*
- *DEPLETION OF OZONE LAYER AND THREAT OF UV RADIATION*
- *POLLUTION OF RIVERS AND INLAND WATERWAYS*
- *POLLUTION HAZARDS OF FOOD CHAIN*
- *DESTRUCTION OF BIODIVERSITY*
- *DESERTIFICATION*

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PRAGMATIC STRATEGIES FOR ENVIRONMENTAL MANAGEMENT

In the backdrop of what has been discussed above, it appears essential to adopt new and pragmatic strategies of environmental management which should consist of at least the following elements:

* Replace the "Pollute-First-and-Clean-later" approach by "Economic -cum-Environmental Planning".
* Environmental quality to match the needs and aspirations of the growing population.
* Minimise the deleterious effects of human and industrial activities through restorative and preventive measures.
* Balance the socio-economic development including the environmental preservation so as to spread the benefits as widely as possible.

Social Role of Engineers in New Strategy

With the adoption of such strategies it is possible to define the social role of engineers in environmental management as follows:

* To appreciate the new demands of the society and not to isolate from the social forces.
* To classify a project for environmental screening based on location (environmental fragility), scale (magnitude of environ-

mental effect) and sensitivity (sustainability or vulnerability of effects).

* To undertake Environmental Impact Assessment (EIA) studies for projects for which environmental screening is essential.
* To select Environmental Mitigation Plans (EMP).
* To fix up institutional arrangements for execution and monitoroing.
* To organise environmental management training.
* To adhere to the principles of sustainability within the limits of practicability and techno-economic feasibility.

The fulfilment of the above roles of an engineer becomes more pertinent in the context of projects already classified as of high priority for environmental screening, some illustrations of which as per the World Bank norms are given in Table 3 [5].

Table 3 - PROJECTS CLASSIFIED FOR RIGOROUS ENVIRONMENTAL SCREENING

- DAMS AND RESERVOIRS
- FORESTRY PRODUCTION PROJECTS
- LARGE SCALE INDUSTRIAL PLANTS AND ESTATES
- IRRIGATION, DRAINAGE, CHANNEL TRAINING AND FLOOD CONTROL
- LAND CLEARANCE AND LEVELLING
- MINERAL, OIL AND GAS DEVELOPMENT
- PORT AND HARBOUR DEVELOPMENT
- RECLAMATION OF NEW LAND
- RESETTLEMENT
- RIVER BASIN DEVELOPMENT
- THERMAL AND HYDROPOWER DEVELOPMENT
- MANUFACTURE, TRANSPORT AND USE OF PESTICIDES/TOXIC/HAZARDOUS MATERIALS

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The most critical role of engineers in handling these projects is to conduct EIA studies for which certain guidelines can be adopted as highlighted in Table 4.

Table 4 - CHECKLIST OF MORE IMPORTANT ISSUES FOR EIA STUDY

- USE OF AGROCHEMICALS IN A PROJECT
- PROTECTION AND MANAGEMENT OF BIOLOGICAL DIVERSITY
- COASTAL AND MARINE RESOURCE MANAGEMENT
- MANAGEMENT OF CULTURAL PROPERTY
- HAZARDOUS AND TOXIC MATERIALS HANDLING
- INDUCED DEVELOPMENT AND ASSOCIATE DSOCIO-ECONOMIC ASPECTS
- INVOLUNTARY RESETTLEMENT ISSUES
- LAND SETTLEMENT
- NATURAL HAZARDS
- OCCUPATIONAL HEALTH AND SAFETY
- INDIGENOUS PEOPLES
- TROPICAL FORESTS
- PROTECTION OF WATERSHEDS, DAMS, RESERVOIRS, IRRIGATION SYSTEMS, ETC.
- CONSERVATION OF WETLANDS
- CONSERVATION OF WILD LANDS
- PRESERVATION OF INTERNATIONAL AGREEMENTS ON RESOURCES

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Faculty Enrichment for Engineers

For more effective functioning in the realm of integrated E-C-E planning, certain preparation is necessary for engineers for enhancement of professional background. A few critical areas of faculty enrichment can be summarised as follows:

a) Innovative approaches for preserving biosphere, selecting cleaner technology and waste management.

b) Development of environmental information systems.

c) Adoption of systems analysis and modelling in environmental management, particularly in view of the multi-disciplinary nature and complexity of sub-system.

In this regard, mention may be made of the endeavour being made by ACC in rehabilitation of quarries, greening of land with appropriate plantations and waste management with new product technologies through in-house multi-disciplinary developmental efforts. In all such exercises, process engineers, agricultural scientists, organic chemists, material scientists, etc. work hand-in-hand.

ASSESSMENT OF SUSTAINABILITY

It need not, perhaps, be repeated that sustainability is the key word in the management of environment but it should certainly be considered that any quantitative assessment of environmental sustainability is always a complex issue. Often attempts are made to measure sustainability through such macroeconomic indicators as:

- Population stability
- Greenhouse gases
- Acidification
- Toxic substances
- Soil degradation
- Aquifers depletion
- Species extinction, etc.

For specific projects, other indicators like energy intensity,material intensity, renewable energy proportion, recycled proportion, etc. are also applied.

But none of these indicators or for that matter, even those developmental indicators like GNP, Price Indices, etc. do not reflect truly the development in a society. Hence, the environmental scientists and engineers, in association with the sociologists, are trying to look at the feasibility of adopting an all together new concept " QOL " - "Quality of Life" - as the proper indicator in economic cum environmental planning. Index QOL is conceived as a function of the objective conditions appropriate to a selected population and subjective attitude towards those conditions held by persons in that population. The mathematical representation of such a concept is obviously not easy, although numerous attempts are being made [6].

CONCLUSION

From the foregoing it is, therefore, obvious that the interrelationship of 'Engineer - Society - Environment' in our planet is an involved one in which there are opposing forces of degradation and restoration, demanding pragmatic management efforts. The practice of technology cannot be kept aside and at the same time, the degradation of environment cannot be permitted. This kind of dichotomous demands needs to be appreciated from what has been stated by Arnold Bacer: "If the practice of technology leads to frequent or dangerous dislocations in the natural environment or in the society, then it is perfectly right to suspect that there is something wrong with the technology itself". This concept is pervading fast enough through the entire society and the engineers are certainly re-orienting themselves to meet the social demands of industrial progress through cleaner technologies and effective waste management. In this approach, there is a strong role of specialised consulting agencies who are already geared up to manage the environment in association with their clients in a pragmatic manner.

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