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# Human dimensions of climate change: Results of a survey of scientists and engineers

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*The extent of scientific understanding and awareness about global climate change plays a crucial role in having informed public debate which is an essential input for decision-making in democratic societies. An opinion survey of more than one thousand scientists and engineers was undertaken to highlight their perception pertaining to: (i) Awareness about scientific understanding of various terms related to climate change; (ii) Environmental concerns and consequences; and (iii) Policy action for improvement of environment and satisfaction with environmental health status. The results of the survey are discussed in the paper.*

RISE in atmospheric temperature witnessed in the second half of the eighties and the present decade is presumed to be the effect of global warming. There is a natural greenhouse effect which is already keeping the earth warmer than it would otherwise be[1]. The prominent greenhouse gases (GHGs) are carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. Emissions of GHGs are causing substantial increase in their concentrations in the atmosphere. This increase would enhance the greenhouse effect, resulting in additional warming of the earth's surface. In recent years there has been a sharp increase in man-made emissions of GHGs. The pre-industrial concentration of carbon dioxide, in the atmosphere was about 280 ppmv and the present concentration about 360 ppmv (ref. 2). The sensitivity of the climate system to greenhouse gas forcing is not yet well known; the assessment – that an equilibrium warming of 1.5–4.5°C for a doubling carbon dioxide concentration in the atmosphere (or an equivalent mixture of greenhouse gases) – remains[3]. The rise in temperature can alter the global climate which may cause melting of polar ice caps, raise sea level, destroy the existing ecosystem and exert varied types of adverse effects on humankind. Recognizing the gravity of the impending crises, the global community has started deliberating on environmental protection and its relationship with economic development. The latter will have to be pursued in a sustainable mode. The global environmental concern came into sharp focus at the Rio Summit in 1992, where a framework convention on

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climate change was adopted; it came into force in March 1994.

Prominent effects of global climate change would be on population dynamics, consumption pattern, food production and food security, access to useable water resources, mode and efficiency of industrial production, conservation of non-renewable resources, use of renewable energy sources, culture and other related activities. It has been realized that effective measures against climate change can be initiated only through an orchestrated global action, which requires international cooperation for evolving a global legal regime. It has also been recognized that understanding of the symbiotic relationship between environment and social and ethical factors could contribute to the formulation of an action plan for environmental protection[4]. The perception and assessment of global climate conditions and changes by governmental policy makers, managers of industrial enterprises and societal groups of all sizes affect how they react to and behave towards these conditions and changes. The assessments and perceptions of individuals on global climate change are largely subjective and probabilistic, and will be affected by many interacting factors, including their individual attributes, their cultural background, social, economic and political setting; and the extent and duration of their exposure to such changes. Jacobson and Price[5] stated, 'For these reasons alone, there will seldom be direct correlations between physical conditions and human perceptions of these conditions. These perceptions, and the many potential behavioural responses to them, will be further modified by the type and content of information provided by media, industry, and governmental and non-governmental organizations with regard to global environmental change and its causes and measures and hypothetical effects at different spatial scales'. Though it is difficult to say with any degree of certainty whether the present level of public awareness and scientific understanding could be directly related to taking of timely action against global climate change, these certainly play a crucial role in having an informed public debate which is an essential input for decision-making in democratic societies. In an effort to have a concrete picture in this respect, the opinions and perceptions of representative groups of scientists and technologists were sought on some issues pertinent to: (i) Awareness about scientific understanding of various terms related to climate change, (ii) Environmental concerns and consequences, and (iii) Policy action for improvement of environment and satisfaction with environmental health status. The selection of issues covered in this survey was made keeping in view the scope of comparison of its results with those of similar surveys carried out in other countries. (The International Social Science Council (ISSC) has evolved a programme on Human Dimensions of Global Environmental Change as an international social science research programme that would parallel and complement the International Geo-sphere Biosphere Programme (IGBP): A Study of Global Change of the International Council of Scientific Unions (ICSU).) Opinion surveys of various categories of public on global climate change in different countries would provide scientists and policy makers an opportunity to understand the levels of public concern in these countries as well as to compare the results of the survey in a country with those of other countries.

## Methodological considerations

A questionnaire was designed to seek opinions and perceptions of scientists and technologists on various issues. It was pre-tested in four scientific research institutions in Delhi. The questionnaire had two parts. Part I, reflected the respondents' profile relating to profession, type of organization, age, sex and the highest academic qualifications. Part II was aimed at soliciting perceptual information in respect of issues concerning human dimensions of global climate change. It sought perceptions of respondents about lifestyle, relationship of environment with economic development, state of environment in the country, awareness about climate change, scientific understanding of environment, sources of information on environment, sources of GHGs and global warming, consequences of changes at local, national and global levels. Views were also sought on the current status and achievements made since the Rio Summit in June 1992 in respect of various regimes and strategies adopted by the Government of India relating to global climate change and environment.

For the purpose of analysis, the total perceptual information has been classified into three categories:

(i) Awareness and understanding of issues relating to global climate changes, sources of GHGs and environmental consequences from the point of view of human security.
(ii) Environment and economic development.
(iii) Local, national and international policies and strategies.

The survey population comprised active scientists and engineers selected randomly from the latest list of members of the Indian Science Congress Association. Copies of pre-coded and structured questionnaires were mailed to about 2000 scientists and engineers. In the event of non-receipt of the questionnaire from them, at least one-time reminders were sent. Completed questionnaires were received from 1061 respondents.

For perceptual responses, two scales were used: (i) three-point scale (i.e. 1, agree; 2, do not know; 3, disagree); and (ii) five-point scale. Suitable descriptors were

used for the five-point scale depending upon the format of the question, i.e. 1, disagree; 2, tend to disagree; 3, intermediate; 4, tend to agree; and 5, agree; and for the purpose of showing the trend of the perception of the respondents, values 4 and 5 were clubbed together as one extreme, while values 1 and 2 were clubbed to represent another extreme transforming the responses on the three-point scale. In addition, multiple options were provided in respect of various questions and the respondents were asked to choose the most suitable ones according to their perception. The data thus generated were analysed using Statistical Package for Social Sciences (SPSS).

In order to study the influence of demographic factors such as profession, age, sex and qualification on the perceptions of the respondents regarding various issues related to human dimensions of global climate change the sample was split into: R&D scientists and teachers in respect of profession; young (up to 35 years) and senior (+ 35 years) respondents in respect of age; Ph Ds and non-Ph Ds in respect of qualification; and men and women in case of sex. The differences in perceptions on various dimensions due to these factors have been studied by computing the chi square values. Generally, the influence of these factors was not found to be statistically significant. However, in respect of few statements, for which these differences were found to be statistically significant at 5% level, they have been mentioned at appropriate places.

## Sample characteristics

Profession-wise, about 58% of the respondents were R&D scientists and engineers, followed by 21% teachers, 6% planners and 15% other professionals. Sector-wise, 72% of the respondents had affiliation with government departments, 7% with private industrial sector and 5% with public sector. A few respondents were self-employed. Age-wise, more than 50% of the respondents were in the age group 36–55 years. Sex-wise, a majority of the respondents (81%) were males; 19% were females. Qualification-wise, most of the respondents were science degree holders. Only 3% of the respondents possessed a degree in social sciences. Doctorate and post-doctorate degree holders constituted 56% of the respondents.

## Scientific understanding of global climate change

The understanding of scientific terms underlying climate change is assumed to reflect the level of awareness of the respondents about issues related to global climate change. Three different options about definitions of various scientific terms were provided to the respondents and they were asked to choose the most appropriate one. The terms given were: biodiversity, global warming, acid rain, sustainable development, desertification, eco-friendly technology, greenhouse gases, ozone hole, El-Nino phenomenon and alternative sources of energy. In respect of 'global warming', 'greenhouse gases' and 'ozone hole' more than 75% of the respondents gave correct descriptions; these were followed by 'alternative sources of energy' (72%). Next in order were El Nino phenomenon (65.7%), acid rain (56.6%) and sustainable development (51%). The least understood terms were desertification (35%), eco-friendly technology (31.9), and biodiversity (31%) (Figure 1). The definitions of these three scientific terms and the respective response rates are given in Table 1.

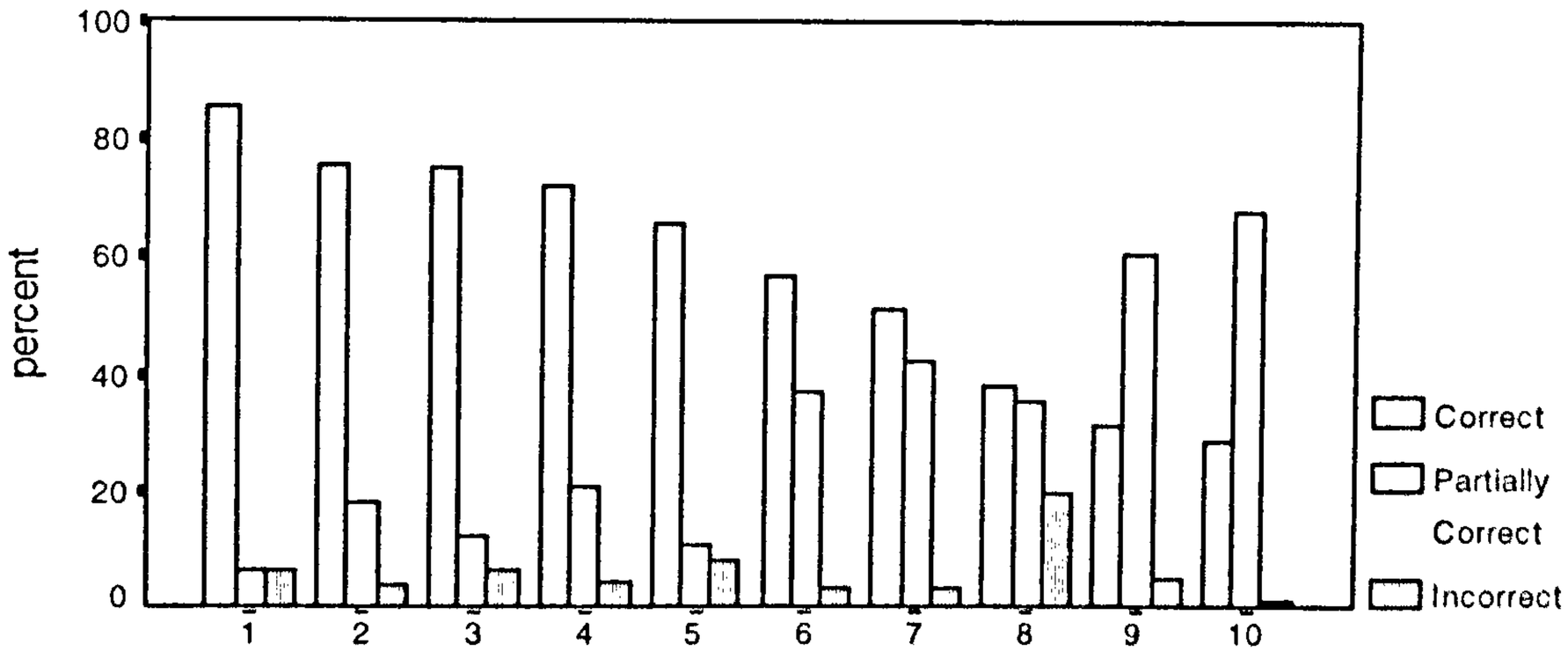


**Figure 1.** Scientific understanding of climate terminology. 1, Global warming; 2, Ozone hole; 3, Greenhouse gases; 4, Alternate source of energy; 5, El Nino phenomenon; 6, Acid rain; 7, Sustainable development; 8, Desertification; 9, Eco-friendly technology; 10, Bio-diversity.

**Table 1.** Perception about scientific terms

| Options for definition of scientific terms | Response rate (percentage) |
|---|---|
| *Bio-diversity* | |
| 1) Bio-diversity is the natural resource that is basic for human life; the preservation of plant, animal and microbial diversity and of landscapes is essential for the well being of humans and for all other organisms. | 31.3 |
| 2) Biological diversity or bio-diversity encompasses all species of plants and animals and the eco-system and ecological processes of which they are parts of. It is usually considered at three levels – genetic diversity, species diversity and eco-system diversity. | 67.5 |
| 3) Bio-diversity is the term used for different forms of plants | 1.2 |
| *Desertification* | |
| 1) Desertification is increase in unpredictable and devastating weather patterns which will lead to species extinction as habitats change and cause desertification; nations could be going to over-scarce water supplies. | 35.7 |
| 2) Increasing area of desert on globe is desertification. | 38.8 |
| 3) Desertification is taken to mean land degradation in dry land regions, and is used interchangeably with dry land degradation throughout. | 25.5 |
| *Eco-friendly technology* | |
| 1) Eco-friendly technologies are technologies based on optimum blend of renewable resources and energy. | 31.9 |
| 2) Technologies which help the environment to remain green are eco-friendly technologies. | 61.1 |
| 3) Technology which is suitable as per the economic structure of society. | 7.0 |

*Under each scientific term the first definition is correct, the second is partially correct and the third is incorrect.

The differences in perceptions were found to be statistically significant in respect of R&D scientists and teachers regarding global warming; senior and young respondents for sustainable development; Ph Ds and non-Ph Ds in case of desertification and eco-friendly technology.

## Sources of greenhouse gases

For assessing the perception of the respondents regarding the significance of different sources of GHGs, a list of natural and man-made sources was provided to them and they were asked to choose the two most probable sources of GHGs. The natural sources included were volcanoes, earthquakes, forest fires, cyclones and wetlands; while man-made sources were oil spills, mining, atomic power reactors, rice fields, automobiles, fossil fuel burning and coolants. With regard to the natural sources, more than 65% of the respondents felt that 'forest fire' was the most probable source of GHGs, followed by 'volcanoes' (51.7%). Only 10 to 15% of the respondents quoted earthquakes and cyclones as sources of GHGs. The differences in perceptions of R&D scientists and teachers regarding earthquake, forest fire and cyclones as sources of greenhouse gases were found to be statistically significant. However, natural sources are not regular emitters of GHGs. Actually they only marginally contribute to GHGs and are of no serious consequence to global climate change. Man-made sources contribute more vigorously to GHGs. The respondents' perception on the contribution of man-made sources was in the following descending order: automobiles (55.6%), fossil fuel burning (54%), coolants (27%), rice fields (14%), atomic power reactors (17.5%), oil spills (13%) and mining (9.7%) (Figure 2). The differences in perceptions of young respondents and senior respondents in respect of oil spills, atomic power, and fuel burning as sources of greenhouse gases were found to be statistically significant. There is no doubt that transport has emerged as a major culprit for accentuating air pollution in metropolitan cities. Some of the gases forming part of vehicular exhausts not only contribute significantly to GHGs, but are also responsible for acid rain.

## Constituents of greenhouse gases

Apart from normal emissions of GHGs, industrialization has created a grave situation through release of huge quantities of GHGs into the atmosphere. Advanced countries, being the forerunners in industrialization, were the first to become aware of GHGs, as they were depending almost exclusively on industrialization for their economic development. It is in this context that scientists were asked to identify the GHGs from a set of gases – carbon dioxide, chlorofluorocarbons, methane, nitrous oxide and hydrogen peroxide. Seventy-one per cent of the respondents identified $CO_2$ as the most important greenhouse gas. The other prominent sources identified were CFCs by 59%, methane by 49%, nitrous oxide by 35% and nitrogen dioxide by 29%. A very

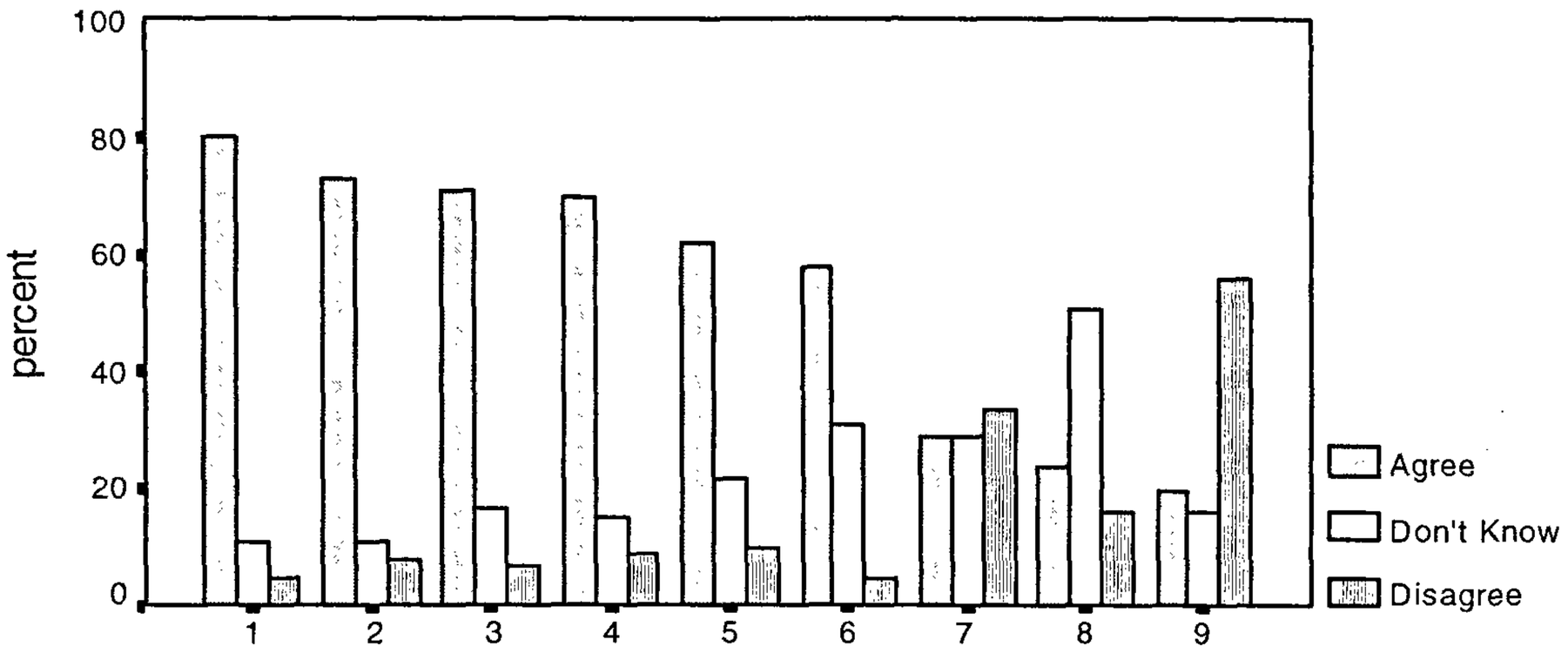


**Figure 2.** Effects of global climate change. 1, Methane from rice fields has contributed in a big way to global warming; 2, Sinks are useful for combating air pollution; 3, Increasing land area under agriculture in developing countries leads to global warming; 4, Ozone depletion leads to skin cancer and cataract; 5, Sustainable development should minimize the global warming effects on human beings; 6, Mean global sea level rise increased between 10 and 20 cm over the past hundred years, a time in which average global surface temperature increased between 0.3°C and 0.6°C; 7, Recycling is an effective way to slow down the build of GHGs and scale back the pollutants that contribute to acid rain; 8, Fossil fuel consumption upsets the delicate balance among atmospheric gases; 9, Modification of consumption and waste disposal habits would help to check alarming and possibly irreversible.

small percentage of the respondents held the view that oxygen, ozone, hydrogen peroxide and ammonia are also constituents of GHGs. The differences in perceptions of R&D scientists and teachers, men and women regarding CFCs were found to be statistically significant.

## Consequences of global warming

A list with eleven phenomena as consequences of global warming was given to the respondents and they were requested to choose three significant ones as per their perceptions in the context of human security. These phenomena were: sea level rise, melting of glaciers, sinking of coastal areas, changes in agricultural pattern, shifting of climate cycles, loss of biodiversity, acid rain, and desertification. Sea level rise was identified as the most significant phenomenon by 62% of the respondents. This was followed by melting of glaciers (52%), sinking of coastal areas (46%), climate changes (46%), loss of biodiversity (35%), changes in agricultural pattern (26%), acid rain (22%) and desertification and other phenomena (15%) (Figure 3).

Another set of questions, each in the format of a statement pertaining to global climate change, was posed to the respondents and they were asked to state whether they agreed or disagreed with each statement. More than 70% of the respondents agreed that ozone depletion leads to skin cancer and cataract (79.6%), fossil fuel consumption upsets the delicate balance among atmospheric gases (76.5%), and modification in consumption and waste disposal habits would help to check alarming and possibly irreversible climatic change (70.0%). Further, a substantial percentage of the respondents felt that recycling is an effective way to slow down the build-up of GHGs and scale back the pollutants that contribute to acid rain and reduce mean global sea level rise, which has increased by 10–20 cm over the past hundred years (Figure 2).

## Concern about climate change

Concern of individuals about global climate change is the direct outcome of their awareness and level of information. Analysis of the responses reveals that about 89% of the respondents were concerned about the status of environment in India, whereas about 2% showed no concern at all. The differences in the perceptions of R&D scientists and teachers and young and senior respondents, Ph Ds and non-Ph Ds regarding their concern about the status of environment in the country were found to be statistically significant. The response pattern is similar to the pattern indicated in surveys undertaken in various countries by the Asahi Glass Foundation, Japan[6].

In addition, the respondents were given a few statements to assess their level of awareness about the extent to which environmental concern is expressed at local, national and international levels. The statements relating to local concern were: natural landscape is being harmed, air pollution has become a serious health hazard, access to open countryside is difficult, water pollu-

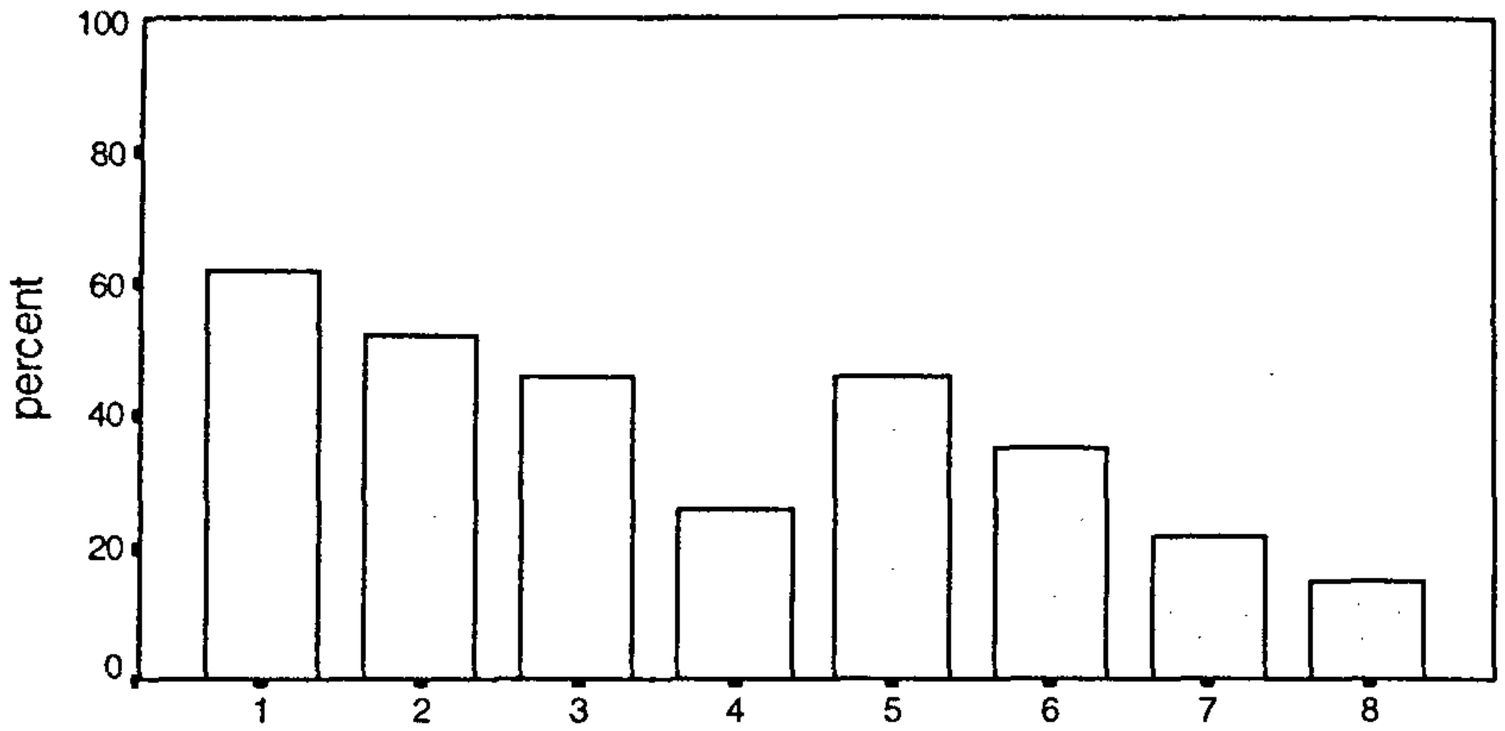


**Figure 3.** Consequences of global warming. 1, Sea level rise; 2, Melting of glaciers; 3, Sinking of coastal areas; 4, Change in agricultural pattern; 5, Shifting of climate cycles; 6, Loss of bio-diversity; 7, Acid rain; and 8, Desertification.

tion is a common phenomenon, devices using alternative energy have yet to establish themselves as efficient systems, and local resources based on decentralized production units must be promoted to meet the local demands. The respondents have perceived worsening of environmental situation as a matter of concern. A majority of the respondents (65%) showed high concern about the natural landscape getting harmed. In their opinion, air pollution has become a serious health hazard (81.8%) and water pollution is a common phenomenon (75.6%). According to 59% of the respondents, devices using alternative energy have yet to establish themselves as efficient systems; about 51% felt the need for promoting the use of local resources in decentralized production units to meet local needs. Positive responses to the statement 'access to open countryside being difficult' were about 43%.

Statements relating to national level concern were: oil spills have jeopardized carbon dioxide ($CO_2$) sinkability of oceans, disposal of nuclear waste is a continuing health hazard, availability of food is likely to be adversely affected, agricultural land use is changing to non-agricultural uses, and soil degradation has become a serious threat. More than half of the respondents (60%) agreed with the statements 'disposal of nuclear waste is a continuing health hazard', 'agricultural land use is changing to non-agricultural uses', and 'soil degradation has become a serious threat'. A substantial number of respondents (48.70%) showed high concern about oil spills, which have jeopardized carbon dioxide sinkability of oceans and 57.89% felt that availability of food will be adversely affected (Table 2).

Statements pertaining to matters of global level concerns were: forest areas are diminishing unabatedly, the fear of extinction of endangered biological species continues, increasing emission of $CO_2$ is inducing climate change, and there is complete hope to achieve international cooperation to limit emission of GHGs. A large majority of the respondents (70%) expressed deep concern about the statements: 'the forest areas are diminishing unabatedly', 'the fear of extinction of endangered biological species continues' and 'increasing emission of carbon dioxide is inducing climate change'. About 44% of the respondents expressed high level of optimism about the statement, 'there is complete hope to achieve international cooperation to limit emissions of GHGs'.

## Lifestyle

The consequences of climate change would be 'limiting availability of natural resources' and 'increased emphasis on conservation of resources'. A new cultural ethos would have to be evolved for future generations particularly with regard to redesigning of our lifestyle. The respondents were asked whether they can adopt a more frugal lifestyle. A consensus is evident on the need to change from throwaway lifestyle to austere lifestyle. 36.2% of the respondents were willing to adopt a more frugal lifestyle, 24.7% had already adopted it, 22.8% were willing to try it out, 11.8% felt they could adopt with difficulty, and 2.1% were not willing to adopt such a lifestyle.

A majority of the respondents were of the opinion that they can adopt a more frugal lifestyle while only 2.1% felt otherwise. The proportion of those who felt that they can adopt frugal lifestyle with difficulty was more or less similar to that noted during surveys done by Asahi Glass Japan Foundation, Japan[6]. The differences in perceptions of young and senior respondents, Ph Ds and non-Ph Ds regarding change in lifestyle were found to be statistically significant.

**Table 2.** Concern about the environment (values in percentage)

| Concern | Level of concern | | |
|---|---|---|---|
| | High | Medium | Low |
| *Local* | | | |
| Natural landscape is being harmed | 64.3 | 21.0 | 7.6 |
| Air pollution has become a serious health hazard | 81.8 | 7.4 | 4.9 |
| Access to open countryside is difficult | 43.2 | 33.1 | 14.7 |
| Water pollution is a common phenomenon | 75.6 | 11.2 | 5.7 |
| Devices using alternative energy have yet to establish as efficient systems | 59.2 | 19.0 | 13.8 |
| Local resources based on decentralized production units have to be promoted to meet the local demands | 51.0 | 25.8 | 15.3 |
| *National* | | | |
| Oil spills have jeopardized carbon dioxide sinkability of ocean | 48.7 | 26.5 | 16.1 |
| Disposal of nuclear waste is a continuing health hazard | 63.2 | 16.3 | 13.4 |
| Availability of food is likely to be adversely affected | 57.8 | 25.5 | 10.0 |
| Agricultural land use is changing to non-agricultural uses | 66.8 | 19.6 | 7.3 |
| Soil degradation has become a serious threat | 71.4 | 16.0 | 6.5 |
| *Global* | | | |
| Forest areas are diminishing unabatedly | 81.0 | 8.8 | 3.9 |
| The fear of extinction of endangered biological species continues | 77.5 | 10.5 | 5.4 |
| Increasing emission of $CO_2$ is inducing climate change | 77.3 | 11.9 | 4.6 |
| There is complete hope to achieve international cooperation to limit emission of GHGs | 43.5 | 31.8 | 18.1 |

### *Environment vs economic development*

The growing thrust on faster economic development poses a serious threat to the environment. The dilemma is that more economic development can be achieved at the cost of environment whereas environment can be protected by sacrificing economic growth. In this context, the respondents were given a set of statements to indicate the extent to which they agree with each statement on a five-point scale. The responses were recast into three-point scale: agree, intermediate and disagree. A response rate of more than 50% is considered as positive or negative for agreement or disagreement, respectively. Analysis of responses to each statement indicates the following preferences of respondents:

87% of the respondents agreed with the statement 'Environmental protection and economic development can go side by side by selecting the appropriate technology'; 70% disagreed with the statement 'Priority should be given to economic development even if the environment is affected'; 63% disagreed with the statement 'Environment protection measures adopted by industry are generally effective in protecting the environment'; 57% disagreed with the statement 'Existing guidelines are adequate for industry to protect the environment'; and 55% disagreed with the statement 'Priority should be given to protecting environment even at the cost of economic growth'.

It could be inferred that the respondents favoured statements aimed at promoting environmental protection. The differences in the perceptions of young respondents and senior respondents, and Ph Ds and non-Ph Ds regarding the statement 'environment protection measures adopted by industry are generally effective in protecting the environment' were statistically significant.

### *Policy dimensions*

Significant policy dimensions relate to international cooperation, solving problems of poverty and overpopulation, altering lifestyles and consumer patterns, organizing citizen groups and introducing appropriate measures against environmental degradation and increasing emission of GHGs. Responses on the effectiveness of policy measures would be indicative of the need for establishing a continuing process of public education and debate for shaping and implementation of policies.

The opinions of scientists and engineers were examined on two aspects covering different dimensions: (i) current status and progress made in respect of environment; and (ii) policy and strategy needed to be adopted by the Government of India to protect the environment.

In respect of various policy dimensions of global climate change since the Earth Summit 1992 the respondents were requested to indicate on the five-point scale the extent of progress made and the adequacy of the current status of environment in the country as follows: Extent of progress made – 1, almost no progress; 2, little progress; 3, cannot determine; 4, some progress; 5, significant progress; Adequacy of current status – 1, completely inadequate; 2, quite inadequate; 3, cannot determine; 4, quite adequate; 5, completely adequate.

The responses were reduced to the following three-point scale: Extent of progress made – 1 + 2, no prog-

**Table 3.** Policies and efforts related to environment since the Earth Summit

| Issues | Extent of progress | | | Current status | | |
|---|---|---|---|---|---|---|
| | SP | CD | NP | CA | CD | CI |
| Efforts to solve basic problems such as poverty and over-population | 22.9 | 10.5 | 55.7 | 26.9 | 9.6 | 51.9 |
| Efforts to alter lifestyles and consumption patterns | 19.4 | 13.9 | 55.3 | 24.7 | 7.7 | 51.4 |
| Activities by local government and citizens' groups | 16.6 | 16.7 | 54.7 | 17.0 | 13.8 | 55.3 |
| Policies to counter global warming | 35.1 | 8.8 | 46.6 | 22.6 | 15.5 | 46.3 |
| Policies to protect the ozone layer | 26.0 | 13.1 | 48.3 | 24.9 | 9.6 | 49.7 |
| Policies to reduce acid rain | 19.8 | 9.8 | 57.7 | 16.5 | 14.2 | 55.4 |
| Policies to control air pollution | 18.6 | 17.2 | 50.8 | 18.8 | 13.7 | 52.9 |
| Policies to promote land use patterns which minimize global warming | 35.2 | 9.4 | 45.9 | 31.3 | 10.8 | 44.9 |
| Policies to decrease consumption of conventional energy in order to reduce the emission of GHGs | 21.1 | 14.9 | 55.4 | 32.1 | 8.2 | 47.3 |
| Policies to conserve forests | 16.4 | 14.4 | 56.2 | 14.1 | 9.6 | 61.3 |
| Policies to combat desertification | 13.7 | 15.4 | 55.9 | 14.2 | 14.7 | 54.3 |
| Policies to preserve the earth's bio-diversity | 14.1 | 14.0 | 58.9 | 12.1 | 14.1 | 58.2 |
| Policies to conserve water resources | 10.9 | 15.6 | 58.4 | 13.7 | 11.6 | 57.3 |
| Formation of recycling systems | 11.1 | 18.9 | 55.2 | 10.6 | 15.0 | 57.0 |

SP, Significant progress; CD, Cannot determine; NP, No progress; CA, Current status adequate; CI, Current status inadequate.

ress made (NP); 3, cannot determine (CD); 4 + 5, significant progress (SP); Adequacy of current status – 1+2, current status inadequate (CI); 3, cannot determine (CD); 4 + 5, current status adequate (CA).

The responses on various statements relating to the 'extent of progress made' and 'adequacy of current status' largely point towards 'no progress' and 'current status inadequate', respectively. The percentage responses on various dimensions are given in Table 3.

More than 50% of the respondents felt that no progress was made in respect of policies pertaining to reduction of acid rain, control of air pollution, decrease in the consumption of conventional energy to reduce emission of GHGs, conservation of forests, combating desertification, preservation of biodiversity and formation of recycling systems. Further, a majority of the respondents reported that no progress was also made in respect of efforts to solve basic problems such as poverty and over-population, lifestyles and consumption patterns and activities by local government and citizens' groups. One-third of the respondents perceived that progress was made in respect of policies to counter global warming and promote land use pattern which minimizes global warming.

The differences in perceptions of R&D scientists and teachers regarding progress made on efforts to alter lifestyles and consumption patterns, activities undertaken by local government and citizens' groups, policies to counter global warming, policies to control pollution and policies to promote land use which minimizes global warming were statistically significant.

A majority of the respondents (45–61%) perceived that the current status of most of the policies on environment was inadequate. Three out of ten respondents felt that the current status of policies to promote land use pattern which minimizes global warming and decreases consumption of conventional energy to have reduction in emission of GHGs was adequate.

### *Policy actions and regulations*

The respondents were provided with a set of statements relating to policies and strategies the government should adopt in the context of global climate change. A large majority of the respondents (79.5%) agreed that industrial corporations should voluntarily take steps to impose restrictions on emission of GHGs. About 77% of the respondents felt that the thrust of national policy on global warming should be to promote international cooperation and to insist on having an international climate regime/code. Around 75% of the respondents expressed that national policy on global warming should not await adoption of international climate regime/code; instead India should on its own initiate steps for preserving the environment. The setting up of a separate financial system for supporting R&D activities and policy studies on global climate change was reported by 77% of the respondents. In respect of specific steps that need to be taken up to minimize environmental pollution, 72% of the respondents advocated adoption of the 'polluter pays principle', and 67% urged the government to apply a legislation for abatement of environmental pollution.

One of the key issues under discussion at the international level is what should be the basis for arriving at the allocation of the global emission of GHGs among the countries of the world and subsequently rationing of GHGs for these countries. The broad features underlying a country's development policies are related to popula-

**Table 4.** Policies and strategies our government should adopt (values in percentage)

| | Agree | Intermediate | Disagree |
|---|---|---|---|
| Thrust of national policy on global warming should be to have international cooperation and an international climate regime/code | 77.3 | 11.6 | 4.3 |
| National policy on global warming should not wait for international climate regime/code but should emphasize steps for preserving environment | 75.9 | 10.4 | 7.9 |
| Control measures should be adopted to limit emission of GHGs and reduce industrial activities that harm the environment | 79.1 | 10.3 | 4.2 |
| Government should restrict material consumption of individuals to protect environment and prevent climate change | 55.9 | 19.1 | 18.4 |
| Market forces should determine the course of environmental action | 32.4 | 19.2 | 40.9 |
| Government should take steps to preclude climate change through appropriate laws | 66.8 | 15.5 | 10.4 |
| Industrial corporations should impose upon themselves restrictions on the emission of GHGs | 79.5 | 9.1 | 4.9 |
| A system should be introduced for charging tax on GHG emission | 66.0 | 12.2 | 15.5 |
| A system should be established for issuing of GHGs emission permits to users and for trading in emission permits | 57.4 | 15.8 | 18.9 |
| Setting up of deposit refund system should be encouraged for promoting programmes for recycling of waste | 74.3 | 12.3 | 6.6 |
| The 'polluter pays' principle should be applied for the abatement of environment pollution | 71.6 | 12.4 | 8.4 |
| A separate financial system should be set up for supporting R&D and policy studies on global climate change | 76.9 | 11.5 | 5.5 |
| At the global level allocation of GHG emission to a country should be done on the basis of its | | | |
| Population | 67.0 | 10.7 | 12.1 |
| Land area | 49.9 | 15.9 | 19.6 |
| National income | 42.9 | 13.9 | 27.9 |

Response rate given against each statement may not add to 100 because of variations in number of respondents who have responded to each statement.

tion, land area and national income. The respondents were asked to indicate their opinions on the rationing of GHG emissions among the countries on the basis of each country's share in the world's population, land area and national income. Their responses in support of each of these features are: population, 67% of the respondents, land area, 50% and national income, 43% (Table 4).

## Conclusions

The respondents included in this survey were degree holders in various fields of science and technology and majority of them were R&D personnel and teachers. They were quite familiar with various environmental issues. They have identified various GHGs and singled out carbon dioxide as a major player in GHG emission. As regard the impact of global warming on human security, the respondents were most apprehensive of sea level rise followed by melting of glaciers and sinking of coastal areas. Only one-third of the respondents could perceive a correct concept of the term 'biodiversity' and a still smaller proportion anticipated the serious threat posed by the loss of biodiversity to human security. The situation was similar with regard to acid rain and desertification. Certainly it calls for creation of awareness in these areas.

The respondents were overwhelmingly concerned about the present status of the environment. At the local level, they have not only shown high concern about deteriorating landscape and air and water pollution as serious health hazards but also felt the need for utilization of local resources in decentralized production and promotion of devices using alternative sources of energy. However, at the global level, the respondents were apprehensive about diminishing forest areas unabatedly, extinction of endangered biological species and increasing $CO_2$ emission.

The lifestyle of people is influenced by their level of literacy and concern about the environment. It is interesting to note that majority of respondents are positive towards adoption of a frugal lifestyle. It tends to indicate that most of the scientists and technologists are unlikely to oppose restrictions imposed by the society on material consumption as measures for environmental protection.

A large number of the respondents were dissatisfied with the current state of the environment and progress made in the implementation of environmental policies. The policy action areas in the developing countries for sustainable development in order of importance as per their perception are: air pollution control, combating desertification and international cooperation.

As regards the government policy and strategy against GCC, the respondents are in favour of introducing taxes on GHG emission and adoption of polluter pays principle. Further, the government should limit material consumption by individuals in order to protect the environment and prevent climate change. It would be desirable that industrial corporations voluntarily impose restrictions on themselves for reducing GHG emission.

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# The Coastal Regulation Zone of Goa: Oceanographic, environmental and societal perspectives

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*Current developmental trends along the coast of Goa offer an opportunity to evaluate the effectiveness of the Coastal Regulation Zone (CRZ) legislation. The mandatory 'No Development Zones' in proximity to, and as buffers for, ecosystems have sufficient oceanographic and environmental validity to be upheld. However, this instrument is being opposed and misinterpreted. Sectoral practices, partisan policies, unbalanced tourism, and absence of political will have all contributed to the CRZ being breached. A national authority that can interact authoritatively with multiple agencies appears to be the only way to attenuate impacts on and restore resilience of coastal ecosystems.*

UNTIL the 1970s, the coastal zone of Goa was largely pristine[1,2]. Subsequently, this zone witnessed a rapid increase in population and a dramatic growth in developmental activities after tourism was avidly promoted[3,4]. Since unplanned development had started along other coastal strips of the country as well, a national legislation, known as Coastal Regulation Zone (CRZ) notification[5], was formulated in 1991. Goa became a focus of the legislation because coastal tourism is a major economic activity in the state.

Socio-economic pressures drive changes in coastal ecosystems. The international programme on Land–Ocean Interaction in the Coastal Zone (LOICZ) has identified four areas of investigations. One of these addresses changes to coastal systems due to social and economic activities. Since coastal tourism and related anthropogenic activities (Figure 1) have intensified during the last two decades[3,4], and considering various adverse impacts of tourism on coasts worldwide[6], the Goan coast offers an opportunity to test the use and effectiveness of coastal legislations with respect to human activity and ecosensitive coastal systems. This paper attempts to analyse issues related to the CRZ of Goa from oceanographic, environmental and societal viewpoints.

The coastal zone of Goa is characterized by sandy stretches and an intricate network of water bodies across lowlands. The sea front is marked by a combination of

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