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GLOBAL ENVIRONMENTAL PROBLEMS OF THE DEPLETION OF THE OZONE LAYER, CLIMATIC CHANGE AND THE RISE IN SEA LEVEL: THEIR IMPLICATIONS IN THE CONTEXT OF THE ASIAN AND PACIFIC REGION

(Item 6 of the provisional agenda)

Note by the secretariat

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CONTENTS

INTRODUCTION

1. The changing chemical composition of the atmosphere in recent years has been a signal of global environmental change. The principal variations observed have been the reduction of stratospheric ozone by chlorofluorocarbons (CFCs) and the build-up of greenhouse gases in the atmosphere.

2. Since 1957, when Revelle and Suess[1/] called attention to man's inadvertent conduct of "a large-scale geophysical experiment" owing to the burning of fossil fuels with consequent carbon dioxide-induced warming of the planet, there has been growing awareness of this issue among the scientific community. Slowly the levels of public and political consciousness have risen, bringing to the fore arguments for taking positive steps to slow the rate of growth of carbon dioxide and other greenhouse gas emissions.

3. This document focuses on the nature of global climatic change and the depletion of the ozone layer. It reviews briefly how these problems will affect the Asian and Pacific region in general, which areas are likely to experience the greatest changes and some of the adaptive measures that can be taken to minimize the impact of global environmental problems in the region. In reviewing the situation, it becomes clear that one's ability to forecast exact change still leaves much to be desired; even general trends are subject to considerable error. Nevertheless, the picture is sufficiently impressive that certain problems can be foreseen which could have a considerable economic and social impact if the world is not adequately prepared. Some precautions and areas of future study and action will then be presented.

I. THE GREENHOUSE EFFECT AND GLOBAL WARMING

4. To no small degree, the interest in climate change has coincided with four of the warmest years in the twentieth century occurring in the 1980s, and the warmest year in many countries occurring in 1989. In Asia and the Pacific, extremes of climate causing severe drought in India and flooding in Bangladesh, China and Thailand have also been observed. This trend continues in 1990, with a warmer summer and the season commencing ahead of shcedule in India and perhaps in some other countries in the region.

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1/ R. Revelle and H. Suess, Tellus 9, 18 (1957), cited in Science, vol. 241, p. 1027.

5. The WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) has stated with certainty that the natural greenhouse effect of the atmosphere is already keeping the earth warmer than it would otherwise be. The emissions resulting from human activity are increasing substantially the atmospheric concentrations of greenhouse gases - carbon dioxide, methane, CFCs and nitrous oxide, and so on - which will enhance the greenhouse effect. This could result in additional warming of the earth's surface.

6. The atmospheric lifetime of these greenhouse gases is determined by their sources and sinks in the oceans, atmosphere and biosphere. Carbon dioxide, nitrous oxide and CFCs are removed only slowly from the atmosphere. Therefore, the concentration of these gases will take from decades to a century to adjust fully to any change in the rate of their emissions. Continued emissions at present rates would result in increased concentrations for centuries. The longer the emissions continue to increase at present rates, the greater the reductions have to be for the concentrations to stabilize at a given level.

7. Furthermore, IPCC suggests that long-lived gases would require immediate reduction in emissions from human activities of only 60 per cent to stabilize their concentration at today's level; methane would require a 15-20 per cent reduction. The effectiveness of the greenhouse gases in the warming process is not uniform: CFC-11 and methane have respectively 4,000 and 58 times more warming potential than carbon dioxide. The increase in carbon dioxide since the pre-industrial period is only 26 per cent, but the combined effect of all the greenhouse gases represents an equivalent carbon dioxide increase of 50 per cent. The proportional contribution of various greenhouse gases in a temperature increase of $3^{o}C$ is shown in figure I. About 50 per cent of the warming may be attributed to carbon dioxide, followed by 25 per cent for CFCs and halons, 8 per cent for methane and the remaining percentage for others.

8. The concentration of atmospheric CO_2 during the pre-industrial revolution era was about 260-290 parts per million by volume (ppmv). By 1960, it had reached (at the Mauna Observatory in Hawaii) 315 ppmv, and at present it is over 350 ppmv (figure II). It is predicted that by the years 2025-2030 the pre-industrial concentrations of carbon dioxide will have doubled. It is for this time period that many predictive models have been formulated.

/Figure I

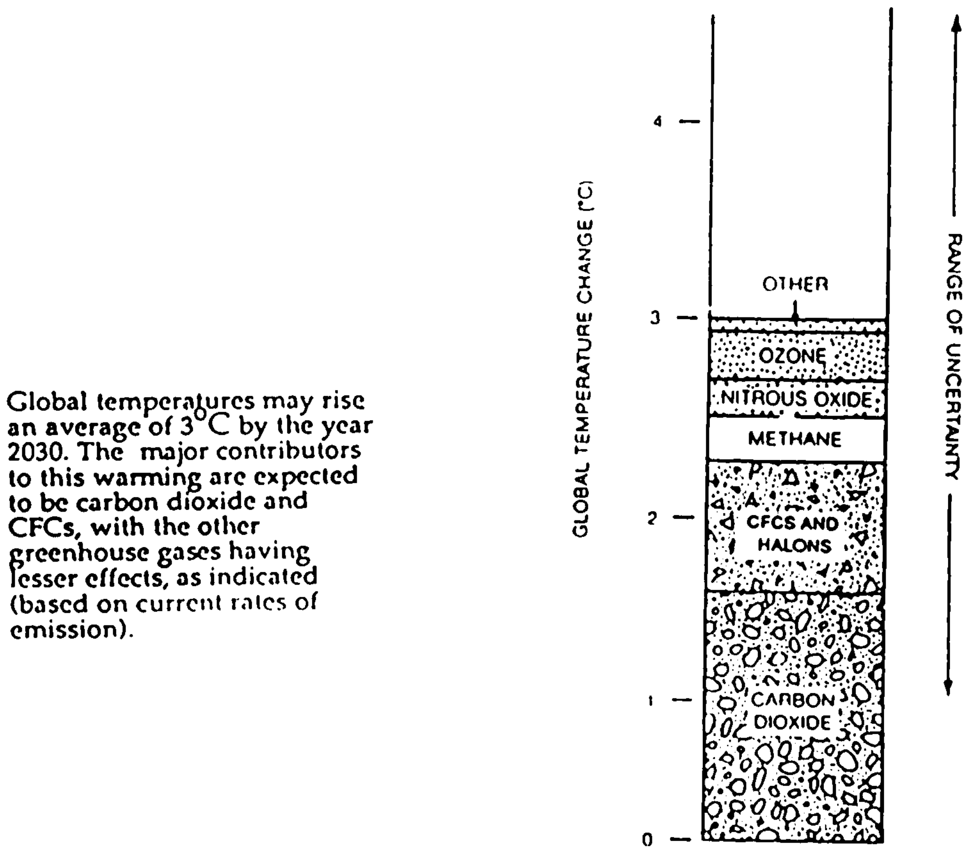

Figure I. Contributions of greenhouse gases to future global warning.

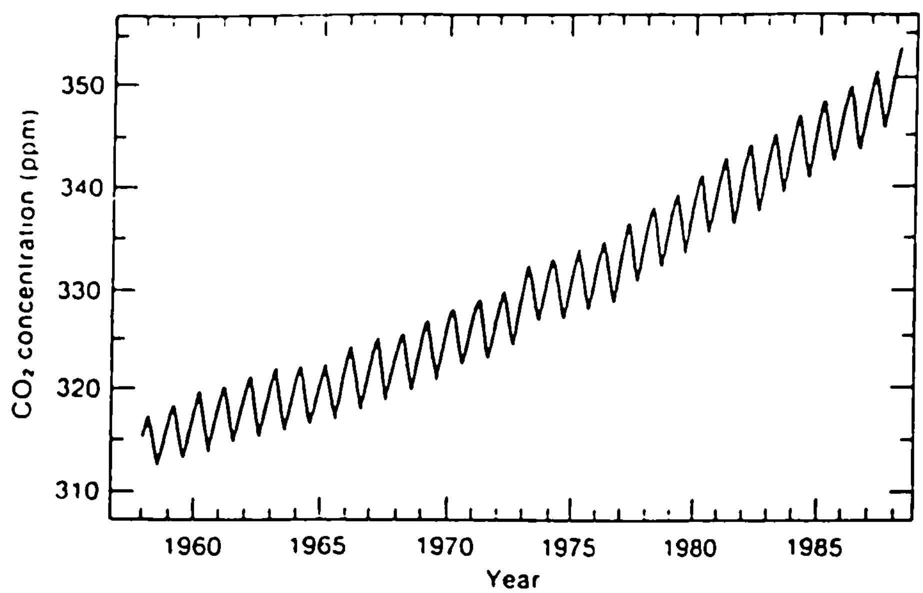

Figure II. Concentration of measured atmospheric CO_2 at the Mauna Loa Observatory, Hawaii (from C.D. Keeling, R.R. Bacastown and T.P. Whorf, "Measurements of concentration of carbon dioxide at Mauna Loa Observatory, Hawaii" (updated) (National Oceanic and Atmospheric Administration/Scripps Institution of Oceanography, Boulder, Colorado, 1988)).

9. General circulation models of the climate system of atmosphere-ocean-ice-land with three-dimensional representation are the most elaborate used at present for climate simulation. However, in the current state of development, the description of many of the processes involved is in a crude form. Because of this, there is considerable uncertainty about the model predictions which are reflected in the range of the estimates.

10. Using the general circulation models with emissions of greenhouse gases in following the IPCC "business as usual"[2/] scenario, the predicted average rate of increase of global mean temperature during the next century is estimated to be about $0.3^{\circ}C$ per decade (with an uncertainty range of $0.2^{\circ}C$ to $0.5^{\circ}C$). This will result in a likely increase in global mean temperature of about $1^{\circ}C$ above the present value by the year 2025 and of $3^{\circ}C$ before the end of the next century. Other forecasts are anywhere from 1.2° - $2.0^{\circ}C$ to as much as 3.5° - $5.2^{\circ}C$.

11. The projected temperature rise up to the year 2100, with high, low and best estimate climate responses, is shown in figure III. The best estimate for the year 2030 is a rise of $0.9^{\circ}C$, and an addition of $0.2^{\circ}C$ will be realized by the year 2050. If the concentration of greenhouse gases increases, the rise will be greater.

12. Even if it were possible to stabilize emissions of each of the greenhouse gases at present levels from now on, the temperature is predicted to rise by about $0.2^{\circ}C$ per decade for the first few decades of the next century. The global warming will also lead to increased global average precipitation and evaporation by a small percentage by 2030. Areas of sea-ice and snow are expected to diminish.

13. The present observations of surface temperature are open to many interpretations owing to the fragmentary nature of the records and the different methods of measurement. Despite this problem, IPCC observed that a real warming of the globe of $0.3^{\circ}C$ - $0.6^{\circ}C$ had taken place over the last century; any bias due to location of the measuring stations in the urban area is likely to be less than $.05^{\circ}C$. Figure IV shows the current estimates of average global mean surface temperature over land and ocean since 1860.

/Figure III.

2/ Energy supply is coal-intensive; on the demand side, there is a modest increase inefficiency; there is some control of carbon monoxide; and the Montreal Protocol is partially implemented.

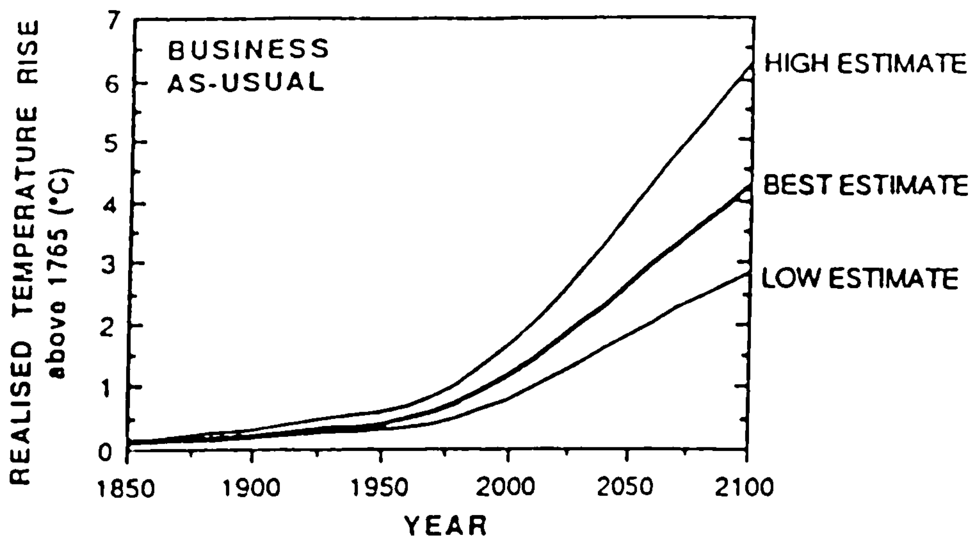

Figure III. Simulation of the increase in global mean temperature from 1850-1990 due to observed increases in greenhouse, gases, and predictions of the rise between 1990 and 2100 resulting from the business-as-usual emissions.

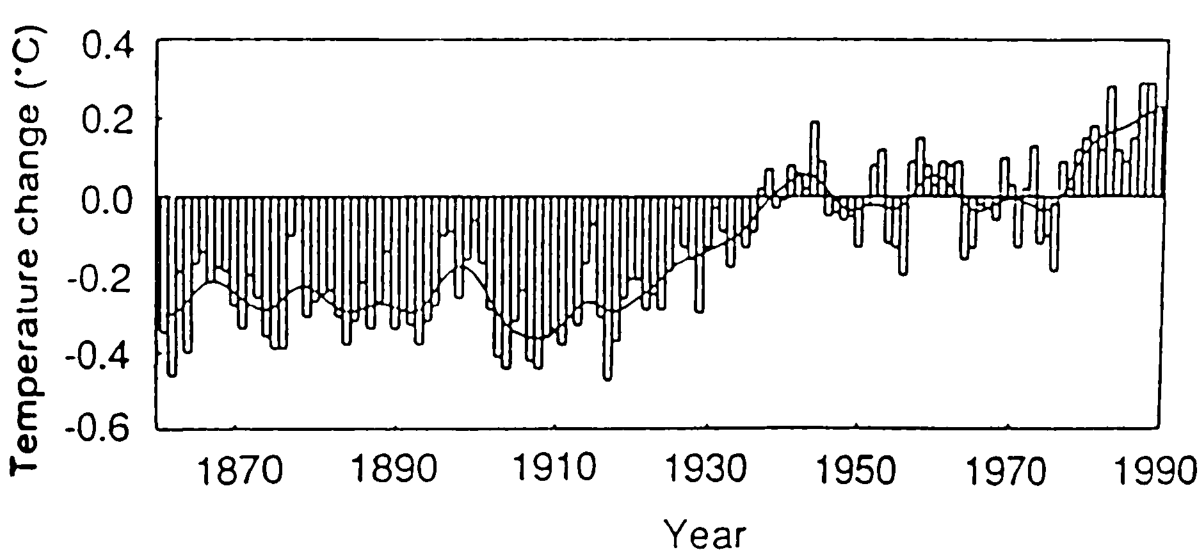

Figure IV. Global mean combined land-air and sea-surface temperatures, 1861-1989, relative to the average for 1951-1980.

14. The conclusion that global temperature has been rising is strongly supported by the retreat of most mountain glaciers of the world since the end of the nineteenth century and the fact that the global sea level has risen over the same period by an average of 1 to 2 mm per year.

15. The extent of the warming over the last century is broadly consistent with the predictions of climate models, and is also within the limits of natural climate variability. If it is assumed that the observed warming was due to the man-made greenhouse effect, then it represents the estimates at the lower end of the range of predictions. The observed increase could be largely due to natural variability. It may also be inferred that this variability may have offset a still considerable man-made greenhouse effect. The unequivocal detection of the enhanced greenhouse effect from observations is not likely to emerge within a decade or so.

II. DEPLETION OF THE OZONE LAYER

16. The depletion of the stratospheric ozone layer is caused mainly by a build-up of atmospheric concentrations of chlorine and bromine, originating from human-induced emissions of CFCs and bromide-containing halons. These chemicals have industrial uses, such as aerosol propellants, refrigerants, foam-blowing agents and solvents.

17. Owing to unique atmospheric conditions, ozone decreases have been most pronounced over the Antarctic. In October 1987, for instance, stratospheric ozone concentrations at latitudes 60°, 70° and 80° S showed decreases of 20, 40 and 50 per cent, respectively, compared with October 1979.[3/] Over the same period, the average ozone depletion at lower latitudes has been greater than 5 per cent, and decreases in ozone have already been detected in New Zealand and Australia.[4/]

18. As a consequence of the depletion of the ozone layer, the amount of ultraviolet (UV-B) radiation reaching the earth will increase. Biologically, UV-B radiation is known to be extremely damaging. For instance, it is estimated that each 1 per cent drop in ozone will result in 4-6 per cent more cases of squamous and basal cell carcinoma, which are the two most

/common

3/ R.T. Watson, "Present understanding of the modification of the ozone layer and its impacts", UNEP programme, Asia and the Pacific Seminar on the Protection of the Ozone Layer, Tokyo, 1989.

4/ R.J. Atkinson and others, "Evidence of the mid-latitude impact of Antarctic ozone depletion", Nature, No. 340 (1989), pp. 290-293.

common types of skin cancer.[5/] This disease is much more common among people with fair skin. Thus, in the ESCAP region Australia and New Zealand may be hit hardest by this consequence of ozone layer depletion. Already Australia has the highest rate of skin cancer in the world.

19. Increased levels of UV-B radiation are expected to weaken the human body's immune system, and increase the occurrence of eye cataracts which may eventually lead to blindness. A weakening of the immune system would further increase the chance of skin cancer or infections. It is feared that, particularly in developing countries situated near the equator, parasitic infections could become more common through this indirect result of increased levels of UV-B radiation. The effectiveness of inoculation programmes, such as those for diphtheria and tuberculosis, might diminish.

20. So far, some 200 plant species, many of them crops, including rice, have been tested for UV-B sensitivity, and about two thirds produced reactions such as a slow-down in growth. Particularly sensitive species include cotton, peas, beans, melons and cabbage.

21. UV-B radiation has the capacity to penetrate to considerable depths in water, and will therefore pose a threat to micro-organisms living near the surface of the ocean. Studies have shown that a 25 per cent drop in ozone would decrease the productivity of phytoplankton by 35 per cent. These organisms are at the base of the food chain of the oceans, and if they became more scarce, commercial fish populations would eventually be affected as well.

22. Increased UV-B radiation levels will degrade synthetic materials such as polyvinylchloride (PVC). The cost of adding the necessary stabilizers to synthetic materials to prevent UV-B degradation in the future would be significant.

23. A paradoxical effect of the depletion of the stratospheric ozone layer is that ozone levels near the ground will increase. UV-B radiation promotes the photochemical process that creates smog, involving ground-level ozone. The process will decrease urban air quality, which is already deplorable in a number of Asian cities.

/III.

5/ C. Pollock Shea, Measures to control ozone depletion, Worldwatch paper 87 (Worldwatch Institute, Washington, D.C., 1988).

III. CLIMATE CHANGE AND AGRICULTURE

24. Scientists describe the sum total effect of global warming and depletion of the ozone layer on the agricultural production in the Asian and Pacific countries in several distinct ways. Colder countries, for example, may experience greater grain production, but in mid-latitude areas cereal production may fall 5-17 per cent as a result of a 2^{o} rise in mean temperature.

25. Precipitation patterns almost certainly will shift. Rule-of-thumb estimates are that present precipitation/evaporation patterns will be accentuated, resulting, for instance, in dry environments becoming drier and being likely to suffer decreased agricultural production.

26. Warrick points out that increased concentrations of CO_2 in the atmosphere may act as a stimulant for increased plant growth. According to his study, for instance, wheat production might increase by 10-50 per cent with a doubling of CO_2 concentrations. Increased carbon dioxide can also help close down plant stomatas, decreasing the rate of evapotranspiration. A recent study by the Commonwealth Secretariat[6/] reveals that a doubling of atmospheric CO_2 concentration may increase the global production of cotton by 104 per cent.

27. For many Asian countries with mean annual temperatures greater than 20^{o} - 25^{o}C, the projected temperature increase of 1^{o}C by the year 2025 would be of minor importance in terms of impact on agriculture. In mountainous areas and countries far from the equator, the projected temperature rise might be of greater relative significance. Subsistence agriculture would move up, as would the zone of endemic tropical diseases which are temperature-dependent (for example, malaria).

28. On the basis of a simulation of a doubling of atmospheric CO_2 levels in several general circulation models, Longxun and others[7/] show that in most parts of China the temperature would increase by about 2^{o} to 4^{o}C. Rainfall and soil moisture would decrease in the northern and central parts of China and increase in the northern and north-western parts.

/As

6/ Commonwealth Secretariat, Climatic Change: Meeting the Challenge, report by a Commonwealth Group of Experts, (Commonwealth Secretariat, London, 1989).

7/ C. Longxun, G. Suhua and Z. Zongci, Global Change of Climate and its Influence on the Cropping System in China (Academy of Meteorological Science, State Meteorological Administration, Beijing, 1989).

As a result of a temperature rise of about 3°C, most of the important eastern monsoon region of China would become suitable for a double-cropping system. The growth period is also expected to increase.

29. Although no systematic, country-by-country impact assessments have been made, the few analyses available give a mixed picture as to the effect of climatic change on agricultural yield. However, given the expanding population in many Asian and Pacific countries, changes in agricultural production can have a dramatic impact on the economic and social well-being of those countries. Clearly such assessments are required for future local and regional planning.

30. Climatic change may also alter forest composition significantly through a combined effect of changes in temperature (both mean and range), rainfall and corresponding factors, such as frequency and intensity of storms and (probably in at least some areas) increased forest fires.[8/]

31. The relatively rapid rate of climate change may exceed the ability of many species to adapt or migrate to more favourable regions, thus posing a threat to biological diversity. In this respect, geographically localized species are among the ones most at risk. In the Asian and Pacific region, with its ecosystem fragmented in general, and in the island ecosystems of the Indian and Pacific oceans, natural migration of various species may not be possible, resulting in their extinction.

IV. CLIMATE CHANGE AND THE MARINE ENVIRONMENT

32. The effect of climate change on oceanic wind patterns is not clear. On the one hand, some models predict intensification of alongshore wind stress, which may lead to an acceleration of upwelling,[9/] and thus probably - at least locally - to increased biological productivity. On the other hand, since land will probably warm faster than the ocean, in many areas the temperature difference between land and sea will decrease, causing an easing of the strength of onshore-offshore winds. As global warming is expected to be more pronounced in polar regions than at low latitudes, the temperature differential between low and high latitudes will decrease, causing global circulation patterns to become weaker.

/33.

8/ For example, J.T. Overpeck, D. Rind, R. Goldberg, "Climate-induced changes in forest disturbance and vegetation", Nature, vol. 343 (1990), pp. 51-53.

9/ A. Bakun, "Global climatic change and intensification of coastal/ocean upwelling", Science, vol. 247, pp. 198-201.

33. Another problem with climate change relates to the frequency and intensity of storms. At least locally, it appears that the intensity and frequency of storms may increase. The impact of greater storms will be felt most in low-lying areas subject to coastal flooding, particularly with the rising sea level.

A. Rise in sea level

34. Rising sea level has serious implications for the coastal environment: retreating shoreline and resultant loss of property and structures; inundated wetlands and lowlands, causing severe damage to mangroves and corals; increased coastal flooding (especially if storm activity also increases); increased intrusion of saline water into aquifers and increased difficulty with sewage storage and/or discharge; altered tidal ranges within estuaries, and so on.

35. It is important to note that it is the relative mean sea level reflecting a change in the relative position of land to sea surface which is significant, and not the absolute rise in sea level. As an example, a coastal area which is being uplifted at the same rate as the rise in sea level will display no local change in mean sea level. As a result, shifts in the relative mean sea level can be related to: (1) changes in water volume owing to the melting of ice (polar and land surface) and thermal expansion of the oceans; (2) changes in sea surface shape; (3) land subsidence or uplifting due, for example, to ground-water pumping or tectonic movements; and (4) changing sedimentation patterns. Global warming can contribute to a change in the relative mean sea level in two basic ways: through increased melting of ice, and through thermal expansion of the oceans.

36. Indications observed from the few long-term tide gauges available in the Asian and Pacific region show a curious trend that mostly reflects regional tectonics.[10/] Nowhere is this more clearly seen than in Japan, where the east coast shows a rise in sea level greater than the world average, whereas the west coast shows net regression of the sea owing to tectonic uplift. Most of eastern Asia shows a rise in sea level up to 2 mm/year, about equal to the world average, but the Korean peninsula and China have experienced falling sea level, again in response to tectonic uplift. In India the evidence is mixed, some areas showing net uplift of land and others a net rise in sea level.

/37.

10/ D.G. Aubrey and K.O. Emery, "Relative sea levels of Japan from tide-gauge records", Bulletin of the Geological Society of America, vol. 97 (1986), pp. 194-205.

37. By the year 2030, most researchers predict an accelerated absolute rise (3-5 mm per year) in sea level. However, local tectonic movements, land subsidence from pumping and coastal sedimentation and erosion can be important factors. In fact, most of the changes in the relative mean sea level appear to have been the result of earth movements rather than changes in the sea level. This is the case in many well-gauged countries, such as India, Japan and Thailand.

38. There are a number of human factors that should be considered in any discussions on the impact of the rise in sea level in the Asian and Pacific region. In this region, population tends to be concentrated in the low-lying coastal areas - which also contain some of the most densely populated urban centres in the world. A population growth of 2-3 per cent is not uncommon in the region, and urbanization is accelerating. In view of this, the potential impact due to rise in sea level assumes particular significance.

B. Mangroves

39. Few ecosystems are as important to the coastal community, and at the same time as fragile, as mangrove forests. Comprising more than 200 species of plants alone, mangrove forests require brackish waters and relatively low rates of sedimentation and subsidence (that is, water depths must be within a rather narrow range, below which the mangroves will cease colonization). Indonesia alone has nearly four million hectares of mangrove forest.[11/]

40. Mangroves act as nurseries for many commercially valuable fish and shellfish, serve as sources of food and wood for local inhabitants, and form a rich and diverse ecosystem and refuge. For example, local fishing from and around mangroves provides 20-60 per cent of the income for households in several village communities along the west coast of Sri Lanka.[12/] Moreover, mangrove forests provide one of the best buffers against coastal erosion.

/41.

11/ UNEP, Management and conservation of renewable marine resources in the East Asian Seas Region. UNEP Regional Seas Reports and Studies No. 65 (1985). E.D. Gomez, "Overview of environmental problems in the East Asian Seas region", Ambio (Sweden), vol. XVII (1985), pp. 166-169.

12/ M.D. Amarasinghe, "Socio-economic status of the human communities of selected mangrove areas on the west coast of Sri Lanka", UNDP/UNESCO Regional Mangroves Project RAS/86/120, Mangrove Ecosystems Occasional Paper No. 3 (1988).

41. Rising sea level may well provide a major problem for mangroves, for the trees are not able to keep up with a sea level rise of more than a few centimetres per year. A relevant example of this problem can be found in the mangrove forests in Bangladesh and Thailand. Unfortunately, however, mangroves are under even more immediate pressure that may devastate them long before the rise in global sea level accelerates. For one thing, mangroves are increasingly harvested for wood. In the Philippines, for example, only about 25 per cent of the original mangrove forests are left.[13/]

C. Coral reefs and coral islands

42. As in the case of mangroves, the problem with coral reefs may well be dramatically accentuated by other man-induced problems. For example, mining of coral reefs in places, such as Maldives and many Pacific islands[14/] has lessened the ability of the reefs to continue to grow. At the same time, poor agricultural practices have increased the erosion of hilly and mountainous areas adjacent to many reefs; the result has been turbid waters that make coral growth (or even survival) very difficult. This environmental pressure may enhance the increased frequency of both coral-related diseases and predators.

43. One of the most critical questions asked by concerned scientists and politicians (as well as, of course, local inhabitants) is the fate of low-lying coral islands. A 2-3 m rise in sea level, for instance, would flood the entire Maldives. Gable and Aubrey[15/] have rated the potential impact of rising sea level for the various Pacific countries, relating the mean elevation of the islands above sea level (figure V).

44. Based on the study conducted for Tongatapu by Spennemann and others,[16/] the following problems can be envisaged with a relative rise in sea level:

/Figure V.

13/ Gomez, loc. cit.

14/ For example, "Environmental problems of the South Asian Seas region: An overview, UNEP Regional Seas Reports and Studies No. 82 (1987).

15/ F.J. Gable and D.G. Aubrey, "Changing climate and the Pacific", Oceanus, vol. 32 (1989), No. 4, pp. 71-73.

16/ D.H.R. Spennemann, L.H. Belz and G. Byrne, "An outline of the potential impacts of greenhouse gas generated climatic change and projected sea-level rise on Tongatapu, Kingdom of Tonga" (Canberra, 1988).

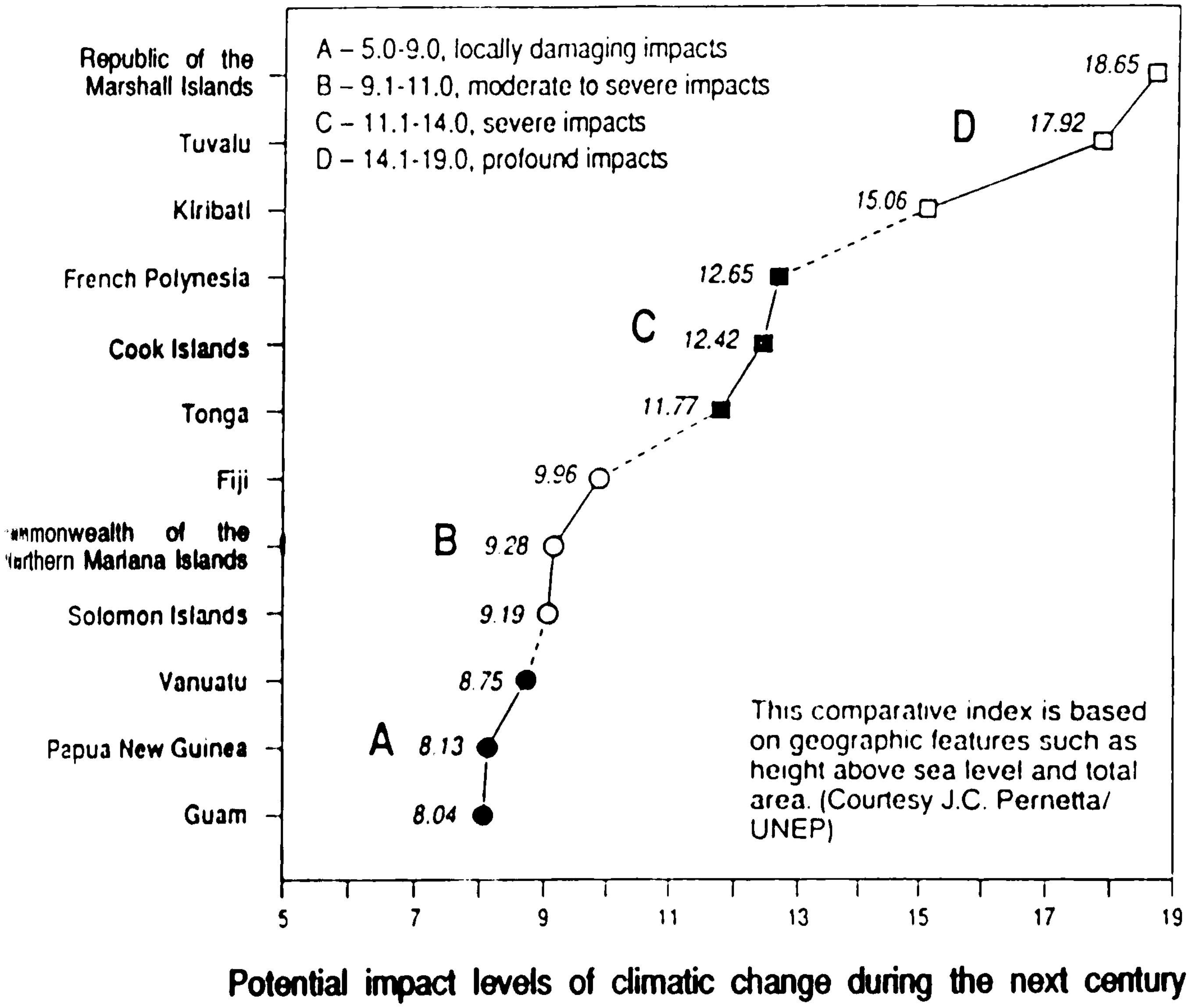

Figure V. Potential impact of rising sea level on Pacific island nations during the next century. From F.J. Gable and D.G. Aubrey, "Changing Climate and the Pacific", Oceanus, vol. 32, No. 4, pp. 71-73.

(a) Perhaps not much actual land loss would occur with a 0.5 m rise, because of the elevation distribution on many coral sand cays and islands. However, a significant area of land would be inundated with a 1.0 m rise in sea level. Some islands might even increase in area owing to redistribution of eroded sediment.

(b) If the relative rise in sea level exceeded 3-8 mm per year, it is anticipated that coral reefs would not be able to cope with this change and would become increasingly submerged.

(c) Erosion would probably increase because of increased wave action - this would occur particularly if coral reefs became increasingly submerged.

(d) The ground-water conditions would change significantly. Usually atoll islets have not running fresh water; they receive their fresh water through rainfall, which is absorbed into the porous sandy soils and rests above the underlying salt water. A rise in sea level of 0.5 to 1 m could dramatically shift the ground-water table upwards. Not only could this lead to more contamination (from salt water) and less actual fresh water for consumption, but also more flooding during rain storms, the result of a shallower water table. The loss of fresh-water table is expected to be particularly severe in small coral islets.

(e) A rise in sea level could have dramatically negative effects on the discharge of sewage into and out of the ground-water system.

(f) With increased rise in sea level, the tidal flat area would increase, perhaps with increased intertidal fish production, although this would depend very much on the health of the adjacent mangrove swamps.

(g) As the sea level rose, there would be less land for farming, compounded by the relocation of people displaced by rising sea level, that is, there would be increased demand for decreased land surface.

(h) The increased salinity of ground water would mean degradation and destruction of low-tolerance plants, such as coconut, mango and breadfruit, none of which can stand a high degree of salinity.

(i) Increased storms might occur, with increased island overwash and increased penetration of salt water into ground water.

(j) Coastal roads might be submerged or severely damaged.

(k) With high levels of natural birth rates, and loss of land, population density would increase dramatically.

45. Many of these problems are exacerbated by the increased urbanization of many of the Pacific islands and the inherent health, social and environmental problems.

D. Land subsidence, deltas and rivers

46. As mentioned previously in this document, even the least optimistic scenarios predict a rise in sea level considerably less than 1 m corresponding to the time by which CO_2 levels in the atmosphere are expected to double relative to pre-industrial levels. In fact, it is increasingly suggested that between now and 2050, the sea level may rise at no greater a rate than it has for the past 100 years.

47. In contrast, particularly low-lying areas can experience natural subsidence rates as high as 0.5-2 cm/year, substantially higher than the predicted greenhouse-induced rise in sea level. The comparison of various sea-level rise scenarious with measured and estimated rates of subsidence for several major deltas is shown in figure VII.

48. Under natural conditions, delta subsidence is offset by the deposition of riverborne sediment, particularly sediment deposited by flood overspill of river banks. Sediment reaching the coastal environment can accumulate in a seaward progradation of the shorefront and/or delta front. Channelling, diverting or damming the river, however, can prevent fluvial sediment from reaching the delta, and thus subsidence may not be compensated by sediment accumulation. Ultimately the decreased flux of riverborne sediment can also result in increased shoreline erosion,[17/] and decreased fresh-water flow can result in decreased offshore biological/fisheries production[18/] as well as diminished mangrove forests.

/49.

17/ J.D. Milliman, "Rising sea level and changing sediment influxes. Real and future problems for Indian Ocean coastal nations", IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs, 1988, Workshop Report No. 37, Supplement, pp. 195-202.

18/ S.D. Wahby and N.F. Bishara, "The effect of the River Nile on Mediterranean water before and after the construction of the High Dam at Aswan", in Proceedings of a Review Workshop on River Inputs to Oceans Systems (UNESCO, 1981), pp. 311-318.

49. Natural subsidence can be accelerated considerably through the removal of ground water or petroleum from the underlying strata - in effect accelerating the compaction of the sediments, one of the natural ways in which a delta subsides. An order-of-magnitude increase in subsidence rates is not uncommon in such situations. For example, in Bangkok, owing to a dramatic increase in population since 1960 and increased pollution of the Chao Phraya river, ground water became a major source of drinking water. The increased pumping of ground water led to a drop in the ground-water level and subsequent subsidence: some areas in downtown Bangkok in the early 1980s were subsiding at a rate higher than 10 cm/year, nearly two orders of magnitude greater than the global rise in sea level. More effective regulation of ground-water removal in recent years has decelerated the subsidence in metropolitan Bangkok, but has increased subsidence in some outlying areas.

50. As rivers become more regulated and populations along the rivers and corresponding pollution levels increase, there will be an increased need to utilize ground water in southern Asia. The lesson of Bangkok (one also experienced in China and Japan, to mention only two other examples) should be remembered, and alternative ways to obtain water should be considered.

V. POLICY IMPLICATIONS FOR ASIA AND THE PACIFIC

51. When planning for future environmental change, it is important to consider not only mean change but also variability and frequency of extremes.[19/] Accentuated seasonal variations, increased frequency of major storms, and occurrence of exceptional storms must all be taken into account. The problem is that the available climate system models give only the most general of trends in terms of mean climate change.

52. Superimposed on regional and global climatic change, however, will be changes in the local and regional environment created by anthropogenic activity. Action such as damming of rivers, human-induced coastal zone subsidence, logging of mangrove forests, mining of beach sands and coastal pollution are only some examples of activities that can accentuate dramatically environmental problems created by global change.

/53.

19/ W.E. Riebsame, "Anthropogenic climatic change and a new paradigm of natural resource planning", Professional Geographer, vol. 42 (1990), pp. 1-12.

53. At present, the humid tropics contain about 8 million km^2 of forest, but this is only about half of what once existed. In recent years, the rate of deforestation of tropical rain forests and mountainous forests has increased dramatically. It is estimated that the rate of deforestation in Asia has increased 35 per cent since 1980. Burning, and slash-and-burn agriculture (plus the amount of CO_2 not taken by photosynthesis) can enhance the greenhouse effect. But deforestation goes far beyond its impact on global warming. One impact is increased albedo and decreased rainfall. Meher-Homji[20/] found that rainfall in an area declined when deforestation in several Indian forest tracts exceeded 15 per cent. Similar effects have been noted in Malaysia and the Philippines.[21/]

54. Perhaps the most effective response to potential global climate change and ozone layer depletion is a mixture of prevention and adaptation. Before policy decisions are made, however, it is necessary to make economic, social and political assessments of future climate and environmental change, for without such assessments it will be impossible to gauge the impact of change or the cost of mitigating the change.

55. Economic analyses of the possible implications of global environmental problems are probably best made at the local level and co-ordinated nationally. While the main parameters of climate change will be assessed at the global level, local studies can shed light on secondary factors. Given the resulting scenarios, a crude cost-benefit analysis can be attempted. It is probably safe to state that in nearly every case these calculations will show that global environmental problems will only accentuate other anthropogenic problems (for example, population and pollution).

56. With these considerations in mind, the following sections list preventive and adaptive action which can be part of a national response to the threats of climate change and ozone layer depletion.

A. Preventive action

57. Clearly two major preventive steps that should be taken by all countries, in particular in Asia and the Pacific, are controlling population

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20/ V.M. Meher-Homji, "Effects of forests on precipitation in India", in E.R.C. Reynolds and F.B. Thompson, eds., Forests, Climate and Hydrology (United Nations University, Tokyo, 1988), pp. 51-77.

21/ N. Myers, "Tropical deforestation and climate change", Environmental Conservation, vol. 15 (1988), pp. 293-298.

growth and encouraging more environmentally sound development in the future. More efforts will have to be made by all Governments to decrease the flux of greenhouse gases to the atmosphere, through both a reduction in industrial and related emissions and increased net afforestation.

58. One could argue that many countries outside the economic "big seven" (Canada, France, Federal Republic of Germany, Italy, Japan, United Kingdom of Great Britain and Northern Ireland and United States of America) have as yet little control over the bulk of greenhouse gas emissions. While such an argument carries considerable weight with many policy makers and some scientists, it can be argued in two ways. For example, deforestation in the Asian and Pacific countries contributes to a small extent to climate change. More importantly, these activities, together with other environmentally detracting ones, can have detrimental local and regional effects. While a small Asian or Pacific country may have little impact on global change in climate, it may play a major role in determining the environmental quality of its own coastal areas. As pointed out by Milliman and others,[22/] for example, river damming and increased subsidence (related to the removal of ground water and/or petroleum) may have as much or more environmental, economic and social impact on Bangladesh and Egypt as even the most pessimistic predictions for the global rise in sea level.

59. In order to be effective, at least some preventive efforts should be co-ordinated at the national and regional levels, but perhaps they can be most effectively co-ordinated through intergovernmental agencies such as the United Nations. UNEP, for example, has formed three Regional Seas programmes that deal directly with regions within the purview of ESCAP - the Pacific Basin countries/islands:[23/] South Asian Seas,[24/] and the East Asian Seas region.[25/] [26/]

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22/ J.D. Milliman, J.M. Broadus and F. Gable, "Environmental and economic implications of rising sea level and subsiding deltas. The Nile and Bengal examples", Ambio, vol. XVII (1989), pp. 340-345.

23/ J.C. Pernetta (Rapporteur), "Potential impacts of greenhouse gas-generated climatic change and projected sea level rise on Pacific island States of the SPREP region", UNEP Joint Meeting, Split, Yugoslavia, 1988.

24/ UNEP, op. cit. (see note 18 above).

25/ Gomez, loc. cit. (see note 15 above).

26/ L.M. Chou and H.T. Yap, "The implications of expected climatic change and sea-level rise on the coastal and marine environment of the East Asian seas region", Pacific Science Association, 6th Intercongress, Chile, 1989 (unpublished report).

60. Joint preventive action will be the only option available to limit the threat of stratospheric ozone layer depletion. Measures to reduce emissions of ozone-depleting chemicals include: (i) improved design, operation and maintenance of air-conditioning equipment, (ii) banning of the use of aerosols in spray cans, (iii) recycling of CFCs in the electronics and flexible foam industries, and (iv) a switch to halon-free fire-fighting equipment.

61. International agreements aimed at saving the ozone layer include the 1985 Vienna Convention for the Protection of the Ozone Layer, and its Montreal Protocol on Substances that Deplete the Ozone Layer, of 1987. Initially, provisions of the Protocol for industrialized countries included a freeze on CFC production (at 1986 levels) by 1989, a 20 per cent decrease in production by 1993, and another 30 per cent cut by 1998. Halon production was object to a freeze based on 1986 production levels starting in 1992. Developing countries were allowed a grace period of 10 years after ratification of the Protocol in which they could increase their domestic consumption of CFCs to 0.3 kg per capita per year, after which they too would reduce their CFC consumption by 50 per cent within 10 years. However, at the second meeting of the parties to the Montreal Protocol, held in London in June 1990, the parties decided to phase out CFCs completely by the year 2000, and expanded the number of substances to be controlled from 8 to 20.

62. So far, 56 States and the European Economic Community (EEC), which together have an 89.6 per cent share in the global consumption of ozone-depleting chemicals, have become parties to the Montreal Protocol. Nine countries in the ESCAP region have ratified it: Australia, Fiji, Japan, Malaysia, Maldives, New Zealand, Singapore, Sri Lanka and Thailand. Other countries in the region are considering becoming parties to the Protocol. China for instance, would sign the Protocol once the following have taken place: (a) an international fund for the protection of the ozone layer has been established, (b) ozone-friendly technologies are transferred from developed to developing countries, and (c) a number of articles in the Protocol considered unfair to developing countries have been modified or scrapped. At the Conference of Select Developing Countries on Global Environmental Issues, held at New Delhi from 23 to 25 April 1990, it turned out that China's view on the Montreal Protocol was shared by many other developing countries.

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63. At the second meeting of the parties to the Monteal Protocol, held in June 1990, a $US 160 million fund was agreed upon to help developing countries build industries which do not rely on ozone-depleting chemicals. It is envisaged that this fund will lower the threahold for developing countries to sign the Protocol. The fund will be expanded by $US 40 million when China signs the Montreal Protocol, and another $US 40 million if India follows. China is expected to take steps to become a party to the Protocol; India, however, has stated that guarantees on the availability of substitute technologies from industrialized countries will be needed to enable it to produce substitute chemicals.

B. Adaptive action

64. As Lave[27/] points out, countries in which environmental agencies are well organized may experience a relatively mild impact from global change, whereas those less well organized countries (often developing countries, most of which have contributed to the global problems to a negligible extent) will suffer most. For example, water supply will unquestionably be an increasing problem; in fact, given the increased economic development and population growth in most Asian and Pacific countries, the lack of fresh water would presumably pose problems even without climatic change.

65. In the ESCAP region, subregional and national meetings held so far have focused primarily on the implications of climate change for coastal areas and atolls. An overview of the results of a number of conferences and workshops which have addressed the question of how to cope with climate change and ozone layer depletion is provided in the annex to this document.

66. Many countries of the region have contributed actively to the work of the Coastal Management Subgroup of IPCC. During recent workshops held at Miami, United States of America, and Perth, Australia, a number of examples of adaptive policies and actions that might help mitigate the rise in sea level in the foreseeable future were formulated:[28/]

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27/ L.B. Lave, "The greenhouse effect: what governmental actions are needed?", Journal of Policy Analysis and Management, vol. 7 (1988), pp. 460-470.

28/ Intergovernmental Panel on Climate Change, "Adaptive responses and policy implications of sea-level rise and other coastal impadts of global climatic change", summary report of the Coastal Zone Management Subgroup (Geneva, 1990).

(1) Identify local coastal management tools and techniques that could be shared with other countries.

(2) Maximize opportunities for saving and conserving fresh-water resources, for example, changing from ditch-water irrigation to drip techniques.

(3) Develop efficient techniques for desalination.

(4) Ensure the adaptability and effectiveness of coastal defense structures to protect against rising sea level through flexible design and long-term maintenance.

(5) Implement a uniform global sea-level monitoring network to document changes in sea level and to enhance predictive capability.

(6) Spray marshes with dredged material slurries to allow the level of marsh to keep pace with an increasing rise in sea level.

(7) Develop wildlife and fisheries management plans and techniques for the changing environment.

(8) Identify and introduce species adaptable to the new environment.

(9) Develop an integrated process for managing a multinational regional ecosystem.

(10) Prohibit subsidies for inappropriate development or compensation for damage caused by the effects of a rise in sea level in vulnerable coastal areas.

(11) Create mechanisms to deal with famine and refugees resulting from a possible rise in sea level.

(12) Negotiate treaties to protect important habitats.

67. As the problem of ozone layer depletion is relatively new, adaptive responses are uncertain and being discussed. In the foreseeable future, the low-latitude countries of the region may not suffer detectably from increased levels of UV-B radiation, but for countries such as Australia and New Zealand it is a different story. It is to be hoped that the lack of adaptive options will enhance the willingness of the countries of Asia and the Pacific to adopt preventive measures, that is to limit the emission of ozone-depleting chemicals to the extent possible.

VI. REGIONAL EMISSIONS OF GREENHOUSE GASES AND OZONE-DEPLETING CHEMICALS

68. At the beginning of the 1980s, the countries of Asia and the Pacific were responsible for about a quarter of the world's carbon dioxide emissions. The CFC emissions were relatively small, but the amount of methane originating from the ESCAP region was quite significant owing to rice cultivation and the large numbers or ruminants.

A. Carbon dioxide

69. Until recently, the contribution of carbon dioxide by the industries in the Asian and Pacific countries was not significant, but this is changing rapidly. In 1950, the industrial emissions of carbon dioxide of the region were only about one seventh those of North America. By 1985, the emissions from the two regions had become almost equal, and both formed about 25 per cent of the global discharge.[29/] A preliminary conclusion of the current ESCAP study on energy policy options in response to climate change is that, if a "business as usual" scenario is followed, the industrial carbon emissions of developing countries of Asia and the Pacific will amount to 2.4 giga tons annually by the year 2010, which is roughly three times the current rate.[30/] This is due to rapid economic growth in some countries and rapidly growing use of coal for power generation. For a given amount of energy generated, coal produces 25 per cent more carbon dioxide than oil, and almost 70 per cent more than natural gas.

70. In 1980, 25 per cent of the world's biotic carbon dioxide emissions originated from South and South-East Asia.[29/] The region as a whole is responsible for approximately one third of the global biotic carbon dioxide emissions.

71. In the ESCAP region, only China over the past 30 years has made continuous afforestation efforts. At present, afforestation programmes are being implemented in India also, and Australia has recently launched a programme which provides for planting one billion trees by the year 2000.

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29/ World Resources Institute, World Resources 1988-1989, report by the World Resources Institute and the International Institute for Environment and Development, in collaboration with the United Nations Environment Programme (New York, Basic Books, 1988).

30/ ESCAP, "Climatic effects of increased fossil fuel burning and energy policy implications for Asia and the Pacific", presented at the International Energy Workshop, Hawaii, June 1990.

72. The use of fuel wood and other biofuels is another source of atmospheric carbon dioxide. According to FAO, shifting cultivation is a major cause of deforestation and a major biotic source of carbon dioxide because the existing vegetation is usualy burnt.

B. Methane

73. The ESCAP region is a significant source of methane due to widespread rice cultivation and large numbers of ruminant livestock. According to the FAO Production Yearbook 1988, over 90 per cent of the world's 1987 rice production originated from this region, and the number of ruminants (cattle, buffalores, camels, sheep, goats) kept in the ESCAP region amounts to over 50 per cent of the world total.

C. Chlorofluorocarbons

74. UNEP,[31/] reports that in 1986 the countries of Asia and the Pacific consumed 149,072 tonnes of the eight substances which were soon to be controlled under the Montreal Protocol, which was about 12.7 per cent of world consumption. Parties included in this figure were Japan, Malaysia, Singapore, Sri Lanka and Thailand.

VII. SUMMARY AND RECOMMENDATIONS

A. The greenhouse effect

75. The atmospheric concentations of carbon dioxide and other greenhouse gases (such as nitrous oxide, methane and chlorofluorocarbons) have increased over the past 100 years to levels approaching double those prior to the agricultural and industrial revolutions. It is expected that the doubling will occur sometime between the years 2025 and 2035. The result is a projected increase in atmospheric temperature. Over the last century, the mean global air temperature has increased by about 0.5°C.

76. Predicted temperature increases over the next 50 years show a great deal of variation both as regards location and between various predictive models. With such levels of variation, most researchers estimate that temperatures may increase between 0.5°C and 1.5°C.

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31/ UNEP, "Revised report on data on production, imports, exports and consumption of substances listed in annex A of the Montreal Protocol", addendum to the report of the Executive Director of UNEP (Nairobi, Secretariat of the Montreal Protocol, May 1990).

77. Estimates of the impact of increased atmospheric CO_2 concentrations on precipitation and evaporation phenomena or on storm activity are less reliable than the projections of global warming. As a first estimate, it is predicted that at present wet areas will receive more rain (at least seasonally), whereas dry areas may receive less.

78. The effect of climate change on global sea level is also less well projected. The predictions of sea level rise of several metres by the end of the next century made in the mid-1980s have been downscaled considerably. The present IPCC estimate for the rises in global mean sea level by the year 2030 is 20 cm, and by the end of the next century, 65 cm.

B. Ozone layer depletion

79. Over the past 20 years, the ozone layer in the stratosphere has been depleted increasingly, primarily as a result of enhanced atmospheric build-up of chlorine and bromine originating from human-induced emissions of CFCs and bromide-containing halons. At present, the main decrease in ozone level has been documented in the Antarctic, particularly during winter months. With depleted ozone concentrations there would be a corresponding increase in degenerative skin and eye diseases. The deleterious effects on human health and agriculture may be considerable.

C. Impact on Asia and the Pacific

80. In Asia and the Pacific, global environmental problems will probably exacerbate the already widespread environmental degradation related to socio-economic development activities (high population density, increasing pollution levels, altered flow patterns of large rivers) and natural physical processes (for example, local subsidence of some low-lying areas). The implications of global warming and rise in sea level for the Asian and Pacific countries are summarized in the table.

81. The direct effects of the greenhouse effect - temperature and precipitation/evaporation change - will be mixed. For many Asian countries with mean annual temperatures greater than 20^{o} - $25^{o}C$, the increase in projected temperature may be slight. Yet locally (for example, in mountainous and more northern areas) the relative rise in temperature may have greater significance. More important may be the altered patterns of precipitation and the general increase in evapotranspiration because of elevated air temperatures. A dramatic change in net precipitation, for example, can greatly affect the success or failure of agricultural harvests

/Table

Table. Major predicted direct medium-term implications of the greenhouse effect and resulting rise in sea level for subregions and countries in Asia and the Pacific

Subregion/country	Major predicted implications	Source
Indian subcontinent	- Combination of local land subsidence, greenhouse-induced sea level rise and coastal environmental degradation may lead to periodic floods, as a direct result of storm surges - Storm surges will become more devastating and frequent - Salt-water incursions will increase - Coastal erosion will become more severe - More intense rainfall and melting of glaciers in the Himalayas will worsen river flooding - Monsoon circulation will become more intense - Local changes in average rainfall will affect agriculture and water supply severely, especially in semi-arid areas	Quraishee, 1988 Milliman, 1989 Commonwealth Secretariat, 1989
Island countries of the South Pacific and Indian Ocean	- Storms will become more frequent - "Hurricane Belt" may extend 20° north and south - Areas with a pronounced dry seasons may experience desertification by 2100 - Coastal flooding (notably Republic of the Marshall Islands, Kiribati, Tuvalu, Maldives) - Loss of fresh-water aquifers - Loss of fish and prawn nurseries in mangrove areas - Coastal erosion - Warming of sea water may lead to coral bleaching and death - Oceanic circulation patterns (e.g. El Nino in the Pacific basin) may change - Loss of biodiversity - Loss of entire islands	Pernetta, 1988 Commonwealth Secretariat, 1989 SPREP, 1989
China	- Deltas of Yellow River, Yangtze River and Pearl River threatened by floods - Mean temperature rise will affect agriculture yields favourably - Rainfall and soil moisture will decrease in the northern and central parts, and increase in the north-east and north-west	Mei-e Ren, 1988 Longxun and others, 1989
Australia New Zealand	- Periodic and permanent floods in north Australia - Coastal erosion in south Australia owing to storm surges and waves - Changes in wildlife regime in arid and semi-arid lands - Existing boundaries between crop- and rangelands will change - Increased frequency of droughts, especially in semi-arid areas	Pearman, 1988 Commonwealth Secretariat, 1989
South-East Asia	- More frequent flooding of the Mekong river and tributaries - Greater intensity and frequency of typhoons	Commonwealth Secretariat, 1989

and river flow. Secondary impacts, such as storm frequency and severity, may be important, particularly in countries that are prone to typhoons and cyclones (such as Bangladesh, south China, the Philippines, Fiji and other Pacific islands) and resultant coastal flooding (such as in Bangladesh).

82. Low-lying land, such as densely populated river deltas (for example, Bengal, Irrawaddy, Mekong, Pearl, Yangtze) or coral atoll islands (for example, Maldives and many Pacific islands), may be flooded, particularly if natural defenses are altered. For example, channelling or damming river flow may prevent deltas from keeping pace with local rise in sea level, thus leading to inundation. Similarly, coral-reef growth could keep pace with the projected rate of rise in sea level for the next 40 years, but many Asian reefs are being increasingly polluted or destroyed by siltation.

83. For many other coastal areas, increased salinization of ground water and the need to modify sewage outflows will require considerable anticipatory planning and effort as well as curative planning. Low-lying urban centres will be particularly affected.

84. While the data base is at present too small to allow accurate projections to be made, it appears that the greatest effect of ozone depletion will be in higher latitude countries. As a first estimate, this problem appears less critical for most Asian countries than climatic changes or (more importantly) other man-made stress on the environment.

D. Recommendations

85. Besides the preventive and adaptive measures already suggested, the following action is recommended for follow-up at international, regional and national elvels (not in order of priority):

International level

(1) To participate in the activities of the Intergovernmental Panel on Climate Change

(2) To ratify the Montreal Protocol on Substances that Deplete the Ozone Layer

Regional level

(1) To develop regional strategies and guidelines for the protection of coastal areas

(2) To enhance scientific and technical co-operation and to upgrade the exchange of information through ESCAP

(3) To support regional monitoring programmes

(4) To develop methodologies to assess the possible socio-economic impacts of climate change and ozone layer depletion, with a focus on coastal zones

(5) To assess the implications of climate change and ozone layer depletion on crop yields and livestock productivity under various types of management

National level

(1) To stimulate large-scale afforestation and to minimize the rate of deforestation

(2) To reduce industrial greenhouse gas emissions through various measures, such as the adoption of energy-efficient technologies, promotion of energy conservation, and fossil-fuel substitution

(3) To reduce greenhouse gas emissions by putting an end to unsustainable slash-and-burn agriculture

(4) To pass a coastal zone act giving the Government full authority over land-use practices in coastal zones. The act should prohibit private exploitation of specific coastal resources, as well as the implementation of development projects within a certain distance of the high-water mark. The act should further provide for the protection of natural coastal defences, such as coral reefs and mangrove forests

(5) To assess the risks to coastal areas and islands of a 0.3-0.5 m rise in sea level

(6) To assess the possibility of leaching of toxic chemicals with a rise in sea level

(7) To control land subsidence through reduction in liquid and gaseous fossil fuel exploitation and ground-water pumping

(8) To maintain the natural flow of sediments to coastal and estuarine areas

/Annex

Annex

MAIN RESULTS OF RECENT (SUB)REGIONAL MEETINGS ON THE IMPLICATIONS OF GLOBAL ENVIRONMENTAL PROBLEMS IN THE ESCAP REGION

SPC/UNEP/ASPEI Intergovernmental Meeting on Climatic Change and Sea-level Rise in the South Pacific
Majuro, Republic of the Marshall Islands
16-20 July 1989

Main results

(1) Findings of the Task Force of the Association of South Pacific Environmental Institutions on the potential impact of climate change on Pacific islands were presented.

(2) Fifteen Pacific countries concluded that those impacts were potentially catastrophic, threatening the very existence of low-lying island countries in the long term.

Commonwealth Heads of Government Meeting
Kuala Lumpur
18-24 October 1989

Main results

Adoption of the Lankawi Declaration on the Environment, which firmly lists the greenhouse effect and the resulting rise in sea level, as well as the depletion of the stratospheric ozone layer, among the main environmental problems facing the world at present. The Declaration calls for support for measures to improve energy efficiency and conservation, and identifies afforestation and improved agricultural practices as means to help arrest the increase in atmospheric carbon dioxide.

Small States Conference on Sea-level Rise
Male
14-18 November 1989

Main results

(1) 18 small island countries adopted the Male Declaration, listing the action which will have to be taken to lessen the impact of rise in sea level.

(2) An Action Group was established, initially comprising representatives from the Carribbean, South Pacific, Mediterranean and Indian Ocean regions, to co-ordinate a joint approach to the problem.

Second Workshop of the Coastal Management Subgroup of IPCC
Perth, Australia
February 1990

Main results

A list of possible adaptive response options to sea-level rise and their environmental, economic, social, cultural, legal, institutional and financial implications.

Conference of Selected Developing Countries on Global Environmental Issues
New Delhi
23-25 April 1990

Main results

(1) Identification of amendments to the Montreal Protocol needed in order to allay the concerns of developing countries. The main points are: (i) ozone-friendly technology transfer and technical assistance should be made available to all developing countries; (ii) an international fund should be established to help developing countries adopt ozone-friendly technology; and (iii) a number of provisions of the Protocol considered unfair to developing countries would have to be modified or deleted.

(2) The responsibility of reducting greenhouse gas emissions rests with the developed countries. For developing countries, incenties rather than targets should be applied to promote a reduction in greenhouse gas emissions.

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