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Item 5.1 of the Provisional Agenda

PAPER ON SCIENCE, TECHNOLOGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

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SCIENCE, TECHNOLOGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Executive Summary

- Technology is a basic element of the relationship between social systems and natural systems. This applies to every technology, ranging from the very simple to the most sophisticated and complex.

- The application and use of technology determines the effects on natural systems and on the social system. Some of the effects on the social system are a direct consequence of the technologies themselves (e.g. greater or less employment, increase or decrease in productivity): other effects are an indirect consequence caused by changes in natural systems (e.g. soil erosion, pollution).

- The effect of a technology on the environment is the result of its special characteristics, or of the intensity with which it is used. Depending on which natural elements of the natural system are affected and the mechanisms by which they are affected, a technology can be predominantly upgrading, conserving or degrading in terms of its effects on a given natural system. The choice of a technology for every concrete situation is therefore of crucial importance.

- Technological choice depends on many things, among them available knowledge and institutional capabilities at the national and local level. The latter are generally lacking in developing countries. It is also affected by ease of access to given technologies, by resources available to the country, the level of development that it enjoys and, more generally, by the balance of political power.

- The concept of appropriate or adequate technology has been discussed extensively over the years, without reaching any consensus. The appropriateness of a given technology does not depend solely on its qualitative characteristics but also is defined by the ecological and socio-cultural characteristics of the place where it is being generated and used. The issue of appropriateness is thus affected and compounded by the fact that over 80% of technology flows in the international market come from relatively few sources in the industrialized world, and are conceived and designed in a socio-economic and ecological setting which often happens to be quite different from that of the importing country.

- In more general terms, the diversity of environment- development contexts around the world is not really taken into account due to the origins of and the process of transnational homogenization of technologies and technological patterns. This points to the urgent need to stimulate the development of alternative technologies and technological systems, that would be more responsive and adaptable to diverse ecological and socio-economic situations, and to establish criteria and mechanisms for the screening and choice of imported technologies.

- The process of generating new technologies, upgrading traditional technologies, and selecting and adapting imported technologies should be informed by environmental concerns. It is important, therefore, to improve such knowledge and capabilities where they exist, and to create the conditions for their existence where they do not. The latter implies, among other things, important changes in educational patterns, in institutional and legal mechanisms at the national level and the creation of the mechanisms and tools to improve access to scientific and technological knowledge and experience, at the international level.

- Up to now, technological solutions to environmental problems have been basically of an add.on character and therefore reactive and curative in nature. Much less has been achieved in designing preventive technological systems that are low or non-waste, and that have less demanding or destructive effects on the natural resource base.

- It is generally agreed that the environmentally sound and sustainable use of the natural resources should be an essential component of the development process. This is also becoming a shared goal of the global community of nations, given increasing economic and ecological interdependence. As a result there is a need for relevant scientific and technological research and development to be carried out by all those in position to do so, and the fruits of such technological advances, be widely shared and diffused.

- The world is at the threshold of fundamental technological changes that will have major impacts on development and environment. While these impacts are still difficult to assess with precision, it is obvious that the new technologies (e.g. bio-technologies, genetic engineering and their international flows) will have to be subjected increasingly to systematic international scrutiny and guidance. Both in terms of benefits most from the new opportunities that they offer, and of checking the possible unwanted effects that they may have. Such scrutiny calls for evolving new instruments and institutions.

- The issue of science and technology, environment and sustainable development is a cross-cutting one and specific recommendations tending to solve outstanding problems and to prevent emerging ones, will have to come from most - if not all - the key issues that the Commission decides to discuss.

I. ENVIRONMENT AND TECHNOLOGY: PROBLEMS AND OPPORTUNITIES.

1. In Chinese, the word "crisis" is composed of two joint characters, namely "opportunity" and "danger". The same symbols could well apply to science and technology in relation to environment and development. Science as the human intelligence put at the service of better knowledge of the natural and social world, and technology as a series of concepts and methods based on science which intend to change the world, constitute the link between society's goals and natural potentials and constraints.

2. Science and technology are a key to progress. More knowledge, increased skills, better practical artifacts are essential to enhance welfare. The vast achievements of science and technology have transformed all walks of life: better health, longer life expectancy, more and much varied consumer goods, closer communication links, etc... But science and technology may also be directed against human progress and development.

3. Over the past decades, new destructive aspects of technology have come to the fore, in the form of various types of environmental degradation. Ecosystems have been and continue to be damaged extensively while replaced by unstable systems. Technology therefore is at the verge of being perceived as a risk factor, and feared as source of endless and irreversible ecological disruption.

4. Science and technology for a sustainable development are a matter of concern to all countries. Many of the present issues cannot be dealt by one country, acting alone. Neither the developed nor the developing countries can protect, for instance, their territorial resources from contaminations that migrate through the air, the waterways, the oceans and the wildlife.

5. But the present world setting is not favourable to an adequate, informed and coordinated response by all countries on an equal footing. If opportunities are to be realized and risks more fully assessed countries need to have more equal access to scientific and technological knowledge, skills and technological goods that enhance sustainable development. Assymetries in the ability to initiate and control informed technological choices and decisions must be reduced.

6. A major purpose of international co-operation on and national policies governing science and technology should be to expand and sustain the ecological basis of development. But this will require major changes in policies, in attitudes, in the institutional structures and in forms of international co-operation.

II. OPENINGS TO AND CHALLENGES OF THE PRESENT SITUATION

7. Encouraging improvements have taken place, over the past two decades, to identify and modify many structural impediments to a better use of scientific, technological and environmental resources. The systematic understanding of the relationships between technology and the environment, and the translation of this knowledge into policies is, however, very much in its initial stages (Annex 1).

8. It is possible to manage the negative side-effects of science and technology and to make use of its potentials, to enhance the environment. The stock of knowledge currently available for this purpose, is far greater now than in any other era of human history. The enhancement of opportunities the reduction of risk - and hence the more effective utilization of the environment -implies at least the following approaches to the development and application of science and technology:

   - the non-wasteful use of natural resources, including non-monetarized items such as air, oceans, space, deep undergrounds layers;
   - the non disruptive use of stable but fragile ecosystems, as for instance the world's frontier ecosystems: semi-arid lands, high-altitude mountains, tropical climax forests, ice-caps, deep ocean beds;
   - seizing opportunities inherent in the dynamic interactions between the component parts of an ecosystem to effect transformations that are more productive and sustainable.

9. New approaches to generate and use environmentally-sound science and technology are in process, but they are not being widely applied. Technologies to satisfy basic needs in human settlements, health, food production and processing, etc... are not being systematically searched, scanned and applied (Annex`2). Opportunities to enhance sustainable development in an economically viable manner are thus not being realized .

10. Most developed and some industrializing countries possess the capabilities to generate new environmentally-sound technologies and to adapt imported technology to fit their own environmental conditions. A greater effort should be put into environmentally appropriate technologies for sectors other than industry. This would, in turn, benefit countries that possess smaller science and technology capabilities and where the critical issues are poverty and biomass-based subsistence. Greatly increased resources should be focussed on priority areas which are crucial for the survival of populations, the prevention of ecological disasters and the maintenance of a sustainable environment.

11. Contrary to current practice, there is a need to be more sensitive to the diversity of possible technological solutions. The uniform application of technology is not viable in the long term. Sustainable development and environmental soundness beg the question of adaptation, adjustment, modification of technology to meet specific society goals and environmental requirements.

12. The need to reverse current practice and thus implement a gradual and non-uniform application of science and technology, has recently been acknowledged to some extent, by introducing curative measures to environmental degradation. However, a curative solution means not only finding ways to reduce the intensity, spread and persistency of pollution and hazards1/, but also phasing out sources of degradation.

13. The second leg of the policy - i.e. the phasing out - has generally been delayed although it is often feasible in a technical sense, whereas reduced pollution and environmental hazards are now well-established objectives in developed countries, at least in the fields that - until recently - presented the most pressing problems to the industrialized countries (organic contamination of surface water, landfills, domestic waste, particulate air contamination).

14. War is the ultimate destructive use of science and technology, and the major controllable source of environmental degradation and spoliation of resources. Yet, military build-up keeps diverting productive activities towards armament production, and holding up the benefits of science and technology. In a number of instances, the constraint on the desired use of technology, is thus, not technological but political.

15. For a great many technologies, already available to enhance the environment, the problem rests with a wider, easier and cheaper access to information and acquisition of skills and knowledge. When knowledge about curative measures is known, immediate financial and economic constraints may prevent governments to promote or enforce technical solutions.[2/] By contrast, in developing countries, even knowledge about the preventive measures is often not available.[3/].

16. Environmental scientific and technological policies are difficult to insert in the development planning process. Their field of influence and control is over-ridden by decisions taken autonomously by individuals and firms. Their results are often unpredictable and emerge over a long period of time. Their achievements are not necessarily measurable in monetary terms.[4/] Promising research is underway to make environmental and technological policies more compatible among themselves and with development planning practices.[5/]

17. There are a number of structural limitations that continue to prevent a broad dissemination of the benefits of science and technology, as well as the full participation of all countries in generation, adaptation and transfer of technology. The still unbalanced position of developing countries is of serious concern to the extent that the adaptation of transferred technology, its environmentally-sound applications, and, moreover, the generation and development of environmentally appropriate technology cannot be the task of a few countries.

18. In the last two decades, most developing countries have established a local R&D capacity to implement science and technology policies. Despite impressive progress made in science and technology institution-building and in training of human resources, Third World research and development still largely depends on foreign inputs, not only for finance but also for their research agenda. The explosion of "appropriate technology" research centres, and the numerous networks set up internationally in most fields of advanced research, have yet to produce major tangible results.

19. The structure of science and technology in developing countries, and the process of selecting priorities for the research and development agenda, often prevents the generation of indigenous technology needed to fill basic needs (Annex 3). Agriculture, the most important biomass-based human activity, and a long-term source of environmental disruption in the Third World, has been neglected[6/] until recent years when basic technological research and development have progressively turned from export crops to subsistence crops.

20. Now some important improvements are coming forth in food production. This type of effort ought to be intensified with two objectives in mind: first, to enable countries to discriminate between different technologies and to alter them in accordance to their social needs and ecological constraints; second, to ensure that the benefits of basic scientific research are transferred to developing countries so that short-term improvements may be obtained. Indigenous capability to assimilate imported technology, to unpackage it and to improve and upgrade traditional technologies is partly contingent upon the availability of skilled personnel, education, training and communication. There is scope for a broadened international action in this field (Annex 4).

21. Scientific research is underway to find solutions to negative environmental impacts, particularly those that affect the functioning of tropical ecosystems. This kind of research often takes place in public institutions set up with national, bilateral or multilateral aid funds, and their findings are later picked up by private firms and developed into some form of commercializable process or product.. It would be desirable that the benefits of such findings reverted to public use. Adequate mechanisms may be found for the implementation of such decommercialization of the component part of technology that comes out of public finance (Annex 5).

22. A combination of legal and planning measures, taken lately by some developing countries, have somewhat reduced the unequal nature of technological flows between the developed and the newly industrializing countries. Measures were established to regulate imports and to improve the local capacity to generate, select and adapt technologies. As a result, technology contracts and agreements vary a great deal with respect to

costs; terms and length of validity; severity of restrictive clauses. The conditions of the technology agreements may have a negative influence on the use of natural and environmental resources and may possibly curtail environmental policies[7].

III <u>SCIENCE AND TECHNOLOGY APPROACHES FOR THE ALTERNATIVE AGENDA</u>

23. The alternative agenda calls for the inclusion of science and technology considerations in all of the key issues. The Commission will therefore need to consider:
    - science and technology as component part of development planning, as well as an issue of economic theory and development;
    - the obstacles to a greater access to the benefits of science and technology;
    - the complementarity of knowledge about technology, the functioning of environmental cycles and systems and the capacity for environmental management;
    - the possible effect on development and environment of certain emerging new technologies.

Technological Policies to Enhance the Environment

24. An increasing number of countries, including some newly industrialized ones, have created a core institution which has the task of formulating and implementing science and technology plans and policies. This body is supposed to perform functions of coordination, evaluation and planning[8], but experience shows, unfortunately, that such functions are not always accomplished. One reason for this is that they are usually not in a position to impose their views on those institutions and firms that make important decisions on development.

25. Effective coordination requires knowledge about the environment concerned and skills. The selection of technologies to be employed is often influenced by foreign funding sources neither familiar with nor even concerned about the local environment in which technologies are applied. Indeed, information on this may not be readily available or accessible[9].

26. Information about the effects of a technology on a local environment and on natural resources use is often packed, inseparably, into the total technology package on sale. Methods of disaggregating a technology package into its

components parts each of which may have a different impact on the environment and resource use, are presently being researched.

27. Environmental impact assessment has often been used to evaluate a project, but usually after the economic and technological parameters have been established, and often after siting has been determined. Alternative methods of impact assessment are being researched taking into account functions assigned to a project (Annex`6). It is important that evaluation takes stock of the functions assigned to a project.

Environmental policies and technical change.

28. Environmental policies have had a considerable impact on technological innovations in developed countries[10/]. They have yielded resources efficient and cleaner technologies in many areas of traditional pollution intensive industrial branches but they have also generated technologies that in the long term transfer pollutants and waste from a media to a more remote one (Annex 7).

29. Barriers to the adoption of cleaner technologies remain significant. The transfer of information appear to be an important factor. Another is that the requirements of environmental protection do not always coincide, at the firm level, with clear advantages such as lower costs of raw materials, energy and waste disposal. Industrial firms are guided by economic risks and marketing strategies and constraints that tend to make environmental considerations marginal in the short term. This is presently true of traditional industries which tend to gear their production strategy towards changing the quality of products already marketed, rather than creating new products. The new emerging technologies with their rapid rate of obsolescence, high degree of secrecy, cross-licensing, high science and information intensity, require a close examination. While these innovations may have beneficial effects on the environment, their diffusion may be hampered.

30. The pattern of industrial concentration and of patents registration and licensing are important indicators of the technological behaviour of firms. Unfortunately, little is known about how they promote or constrain the use of cleaner or environmentally appropriate technologies[11/].

Environmental policies and transfer of technology.

31. Moreover, little is known about the effects of environmental and other policies in trade in and transfer of technology among industrialized countries, or between developed and developing countries. In so far as firms have to comply with national regulations, the scope and severity of which varies greatly, it can be expected that environmental policies may have an influence on the international diffusion of cleaner technologies, as well as on the re-location and export of polluting technologies. Little information is available on the extent of the transfer of anti-pollution and cleaner technologies to Third World industries, or on the transfer of polluting technologies, as well as the reverse transfer of technologies identified in the Third World[12/].

32. In the 60's and 70's importing countries place emphasis on the social and economic effects that technology had at the national level. Due to financial constraints , concern with costs rather than with the characteristics of technology itself appears to be a more recent feature of technology imports by developing countries. Financial constraints also induce cutting down purchases of technology abroad: single components parts are imported rather than a whole technological package. The risks of establishing industrial plants assembled in this fashion, with the guidance of only financial parameters, should be investigated. Another consequence of the present trend needs attention: in so far as environmental impact studies assess new ventures only and not project extensions, it may be that piecemeal technical change has a similar environmental impact as large projects.

33. The export of hazardous industries to developing countries is known to have taken place in the 70's, particularly as a result of the the emergence of the "not-in my-backyard" syndrome and of the stronger enforcement of environmental regulations in the industrialized countries. South Korea, India, Taiwan and Thailand have been cited as among those countries that have provided alternative sites for hazardous industries, as well as Mexico, Peru, Brazil, Bolivia, Namibia and Botswana. These have included copper and zinc smelters, asbestos textiles, pesticides, PCV's.

34. The movements of hazardous industries around the world are not monitored, nor is the sale of products banned or severely restricted in the countries of origin. Despite statements to the effect that the same standards governing a technology should apply in the country of origin as in the recipient country, there is no international agreement as to actions that need to be taken. The Commission will have an opportunity to consider this under several agenda items. A specialized agency, modelled after the IAEA, has been suggested as one way of dealing with the diffusion and use of hazardous technologies, but many other forms of international cooperation in this area may be considered.

<u>Assymetries common to all key issues</u>

35. Action on the relationships between technology and environment must consider four types of assymetries that adversely shape sectoral policies and their related economic and trade policies.

36. <u>First</u>, there is a gap between theory and practice, between pronouncements and action. The idea that technology ought to be conceived as part of a wider context has gained some ground in recent years, thanks to growing concern about their environmental implications. But the practical application of science innovations in technological research and development projects are still not widely viewed in relation to the environment: they are applied, as it were, in parallel, to the environment.

37. <u>Second</u>, a major gap exists between science and technology as instruments for the accelerated pace of economic and social development, and the established structure of international technology flows. Limitations on the broad dissemination of science and technology affect every key issue on the Commission agenda. Their specific forms - the particular conditions of generation, adaptation, diffusion and trade - have to be highlighted. Similarities and differences must be recognized and used as an input to the general perspectives issue.

38. A <u>third</u> gap, related to the above, is growing. It concerns the direction and content of scientific and technological research and its relevance to the real problems of different regions and countries. In the industrialized countries, the over-riding concern has been environmental pollution by industries. But, while some developing countries also need to

address to problems created by pollution-intensive industries, they have on top to deal with additional pressing problems, namely the management of ecosystems by the rural population and the fulfilment of basic needs.

39. Finally, the last 15 years have witnessed a large amount of scientific and technological projects leading to innovation and a growing gap between the knowledge and experience acquired through this piecemeal approach and the institutional capacity for overall policy guidance, based upon issue-oriented assessments that cut across sectors.

Environmental and Technological Risks: an issue related to the choice of technology

40. The environmental impact of technology feed backs on society which perceives the impact as a "quality" change - rather than the result of a previous technological choice. If the "quality" of the environment is noticeably different over the span of a few generations, the impact will eventually be perceived as a boon or as a threat to health and survival.

41. Obviously not all environmental risks are a direct consequence of the effect of technology. In many cases, it is the lack of technology that multiplies risks and results in crowding, poor sanitary conditions, soil erosion, sheer poverty and others. There is, however, some evidence that a number of technologies have a greater negative impact on the environment of the poor (Annex 8).

42. The effective choice between technologies - or, to put it in more general terms, the choice between solutions needed to answer a given issue - cannot take place unless decision-makers possess a good knowledge of the issues involved. It is the realization that certain technological choices can have critical consequences for the future - some of which are difficult to reverse even in a long-term horizon - that have prompted the institutionalization of technology assessment bodies. The question of effective choice is even more important to developing countries where technology is still too often implicitly selected by the source of foreign-exchange finance.

43. Technology tends to reinforce a whole pattern of attitudes, conduct, life-styles - which can be positive or negative according to the value judgement applied - but affect basic aspects of an individual's life such as working conditions, the quality of living conditions, the management

of time, notions of danger, ability to make accurate choices, etc... Unfortunately, little is known about the overall effects of technology on society, the ways and means by which technology reinforces the elements of a social structure that are not conducive to development, and the ways and means by which a transformed environment (as a result of negative technological impact) influences the individual and collective perception of society.

44. The arguments in favour of more equitable social control of technology, in the light of the opportunities and threat it may present to health and environment, were re-affirmed in recent years. To implement such control, a number of necessary conditions are:

- better knowledge of the pros and cons of a given technological choice,
- better grasp of the synergetic effects of technological and environmental policies,
- greater efficiency in environmental management,
- scaling down production processes where possible to a more human scale, to make them more compatible with other social and economic objectives,
- assessing the longer-term viability of new technologies,
- up-grading the basic technical culture in a society, i.e. the individual's understanding of technology and technological processes

45. From an environmental point of view, the choice of technology involves consideration of a number of difficult questions, such as the responsability of the generator of the technology for the damage its product may cause; the need to consider waste and pollution as a product; norms and methods for the evaluation of hazardous technology; appropriate threshold values for certain types of low-level exposures to man-made substances, etc...

New Technological Breakthroughs

46. Emerging technologies (micro-electronic-based technologies; bio-technologies; new materials technologies; laser technologies; space, marine and sea-bed technologies) have begun to affect practically all sectors of the economy. New functions or qualities are given to existing processes and products. New products are created. New industrial branches and new production systems are being developed (Annex 9).

47. Many emerging scientific and technological innovations are bound to have a significant impact on development and the environment. They are typically science-intensive. They are characterised by labour savings. They often economize on weight and volume. They may consume less raw materials and energy and use waste-products. They may allow a flexible, decentralized location of productive and support activities. Unfortunately, these technologies are often protected by a high-degree of secrecy and licensing practices that may hamper broad access and their diffusion.

48. It seems that new technologies may have rather positive effects on the environment basically through the prevention of some problems which have been commonly associated with technologies so far. Nevertheless, some negative effects on the environment can also be encouraged. These may stem directly from the characteristics of the new technologies, or indirectly through their impacts on social and economic aspects of the development process. Therefore, it would be convenient to accept them having, at the same time, the care to monitor closely their development in order to steer the process of their use in such a way that major problems may be prevented.

FOOTNOTES

1/ As a result of integrated pest control on cotton plantations in Central America, not only have yields increased but fever cases of pesticides poisoning were reported, and the quantities of chemicals applied were greatly reduced. Similarly, several advanced technological methods are being investigated to apply nitrates in more exact proportion to plant needs in order to reduce its seepage to the groundwater and streams.

2/ For example, only two of the ten largest cities of Latin America have integrated programmes to monitor and reduce air pollution, and were able to do so with World Bank loans. In Sao Paolo (Brazil), the programme met the resistance of the industrialists who would not take advantage of the soft loans available to buy less-polluting technology, because it entailed the bank's supervision of their production activities. The programme started behind schedule when the bank agreed to finance energy equipments, mainly to switch from thermal to electricity supplies.

3/ In 1977, the UN Water Conference pointed out that "all evidence submitted by the various UN specialized agencies indicates that the major problem is not lack of technology for water resource management, but rather a failure to choose the appropriate technology and/or to maintain the technology in operation once it is in place".

4/ Common features of environmental planning and science and technology planning partly explain why they were long neglected by planners and policy makers:

i. Both sets of policies aim at influencing decisions that are taken autonomously, at the firm, at the individual or at the collective level, but which have effects that go beyond the time and spatial horizons of those responsible for the decision.

ii. Environment and technology policies share a common long-term perspective. Significant innovations, technological change and environmental enhancement cannot be expected in the time periods of a single development plan. They progressively build-up over span-periods of 20 to 50 years and more.

iii. The nature of the expected results is also similar. Results are typically uncertain and diffused: benefits accrue at a largely unpredictable pace; many negative effects have unforeseable degrees and forms of occurence, while the time-lag and place of occurence are uncertaintly known.

iv. One important beneficial consequence of environment and technology policies is to highlight the weaknesses of current development planning. Established planning practice is unduly limited to factors that can be quantified in monetary terms. Consequently, only quantitative indicators are used to assess results. Qualitative change is inappropriately grasped.

5/ A possible promising method is summarized herewith: It consists in identifying and choosing technologies out of a matrix where human needs, environment as a supplier of resources, and environment as a receiver of man-made products are matched against five requirements for technological choice: information, ex-post corrective measures, corrective measures at source, preventive actions in production and consumption, and preventive actions in relation to life-styles and development choices.

6/ Productivity per person (a measure of the technological gap) is 1 to 12 between the developed and the developing countries.

7/ Some examples are provided to illustrate this point.

i. A technological contract , involving the use of a patented product, may forbid the importing country to work on a local substitute. The receiver of the patented technology is, in a way, prevented from adapting the imported product, an adaptation required by environmental conditions prevailing in the importing country.

ii. A technological contract may also prevent the receiver to change inputs. As a result, locally available raw materials, that could provide less wasteful inputs and less contaminating outputs, cannot be used.

iii. Another example is provided by contractual conditions that prohibit industrial process adaptation of the imported technology. If there were cheap ways of making the process less polluting, the innovation would not be introduced.

These issues have been investigated but the information available needs to be processed in a usable form.

8/ The first function of a technological planning institution (or institutions) is to act as a clearing house and coordinating agency for the identification and selection of relevant technologies, the dissemination of technological information, the election of the source of supply of technology, the registration and monitoring of transfer of technology agreements. The second function is to evaluate specific technologies available. The last function is to formulate an integrated plan, and to forecast technological options within a comprehensive strategy.

9/ Access to the sources of information is generally impractical: there are reportedly 5,000 data banks and information services currently available on terms and sources of technology. Most countries do not have the organized capacity to use information efficiently, nor do they have a ready access to it.

10/ With respect to the industrialized countries, a recent OECD study states that the overall R&D effort has been marking time since the early 70's. The share devoted to the development of clean technology is not known, because expenditure on this research is assigned to the industrial sector concerned (industry, energy, etc.). Public R & D for environmental protection (research on the causes and the effects of pollution, and on end-of-pipe pollution controls) ranges from 1 to 3 per cent of total public R&D, whereas energy represents over 10 per cent of public R&D expenditure in most industrialized countries.

Unfortunately, no data is available to compare R&D for energy-saving technology with efforts to generate clean technology, although there is a very probable overlap.

Apart from public R&D, the OECD reviews a number of environmental policy instruments that affect technical change at the firm level:

- enforcement of standards, pollution charges, technological requirements stated in the environmental regulations,
- financial aid for investment and operation of end-of-line or clean technologies,
- financial aid programmes for R&D carried out by industrial projects or industry associations,
- government provision of technical information,
- government procurement policies.

Industrial firms in developed countries have responded to these policy instruments, mainly by generating end-of-pipe technology. A case study of innovation in the US industry points out that about 80 per cent of all pollution abatement investment went to generating end-of-pipe technology.

11/ The scattered information available indicates that this field should be researched more. According to a report, between 1970 and 1981, the number of major US pesticide producers declined from roughly 80 companies to about 30. By 1977, nearly 100% of the herbicides and 80% of the insecticides for corn, used in the US, were produced by only 4 of these companies. Over 75% of herbicides and insecticides for soybeans were also produced by only 4 companies. Another example, from a chemical industry publication, illustrates the geographical concentration of innovations in environmentally appropriate technology, usable by in the chemical process industries: out of 78 major technical developments, 3 came from developing countries, 1 from the USSR and the rest from the OECD countries.

12/ Apart from odd references pointing to the existence of idle plants for municipal waste recovery - probably fit for the industrialized countries' waste "basket" - and to the difficulties of operating biogas plants, a thorough research is still on the agenda . It should cover not only industrial technologies, innovations in the field of biotechnologies and renewable energy, but also scientific developments based on plants, crops, trees and animal resources which have been identified in the developing countries. To what extent are new technologies - identified in LDC's - transfered to industrialized countries ? Jojoba and Kiwi cultivation are some examples. The terms, costs and benefits of the transfer of these new technologies and scientific breakthrough should also be assessed.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT

ANNEXES TO DOCUMENT WCED/85/3

SCIENCE, TECHNOLOGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

The Relationship Between Technology and Environment

1. Knowledge of the ecological cycles and systems is being incorporated - even if slowly - in the conceptual schemes that relate technology to environment, as part of the development process. A new conception of technology is emerging as the man-made conditions in which a process of conversion of materials and energy takes place, to yield products that are directly usable (end-products), by-products that are generally neglected and considered worthless waste, and energy that is dissipated. Thus technology may be regarded as the cluster of instruments and skills that are fashioned by a given society and coordinated for a given purpose, which web ranges from the extraction of raw materials and the generation of energy up to the elimination of waste after consumption.

2. Technology as a process of conversion implies that all the materials initially present at the start of the process re-appear at the end, in one form or another. But technology is not a process of conversion that takes place spontaneously, as conversion does in the ecological cycles. It is designed, monitored, directed by men who exist in a specific context (social, political, economic, environmental, time and space-wise) and who have previously acquired scientific or practical knowledge and skills. Technology carries the stamp of the society, the culture and the natural environment in which it is generated, developed and successfully applied. Therefore, different parameters shape the process as a result of the societal and environmental conditions prevailing when and where technology is used.

3. As a general rule, it can be said that the less the conversion process functions in a sealed closed-circuit, the more operational variants exist, the less perfectly replicable the technological process will be, and the more varied will be the total mix of its output. At present, estimates of the efficiency of industrial technology, in terms of the use of natural resources, range from 5 to 10 per cent on average.

4. Both the variability of the results obtained from a single technology, and the diversity of its impact on the societies who make use of it, are indicators of the relationship between technology and society. In so far as the linkage between society, technology and environment is not supposed to belong to the field of planning, impacts of technology are bound to remain obscure and will not be properly managed. If all of the relationships were incorporated into the scope of planning, characteristics such as uncertainty, variability and diversity of results, as well as imbalance, desequilibrium, non-equivalence and non-equilibrium of inputs and outputs, could be accounted for as measurement towards improved technical efficiency.

5. The new conceptual frameworks are important for:

   i. the future inclusion of science in the linkage between technology and the environment: up to now science and technology on the one hand, and science and the environment on the other hand, are issues that have been usually dealt with separately;

   ii. the improvement and the adequacy of the instruments of economic analysis and development planning, so that environment become a dimension of development in its own right and ceases to be included in the planning process as an external constraint;

   iii. the establishment of specific policies that enhance the emergent relationships between technology and the environment, thus changing the present practice that separates science and technology policies from environmental policies;

Environmentally Appropriate Technologies for Developing Countries

1. Starting in the early 70's, both governments and industry in the developed countries put a lot of effort into scientific research and its application for the generation and diffusion of environmentally appropriate technology. It is basically the developed countries' industry, energy and sanitation sectors that have benefited most from the resulting technical innovation and change. Beside innovations of concern to the traditional polluting industries, environmentally appropriate technology has not affected greatly other sectors of the developed economies (agriculture, transport, mining, etc.).

2. The specific technological problems of the branches important to developing countries - namely agriculture and food processing, energy, construction, water supply and sanitation, basic consumer goods - have received a mixed interest from the world scientific and technological community. Much work is scattered around in the developing countries themselves, and is at various stages of development, from a scientific to an applied level. The overall picture is swarming with activities that have reached different stages of research, development, commercialization and diffusion, that are sometimes connected by international and often overlapping networks of scientific and technological institutions, and - above all - that lack of a global cohesion, purpose and direction.

3. A number of steps could be taken at the national and international level, to streamline the most obvious weaknesses:

   i. reinforced coordination of research activities and development projects, particularly within multilateral and bilateral networks and programmes, in the fields of resource-saving technologies, less polluting industrial technologies and auxiliary technology as outlined in the attached checklist.

ii. generating an increased and better-shared knowledge on the state of the inhabited "ecological frontiers" (deserts, semi-arid lands, high altitude, tropical forests), to gather and scientifically apply the resulting knowledge of the conditions in which technology is presently used to build-up new sustainable ecosystems (micro man-made ecosystems);

iii. generating interest within the world scientific and technological community and among governments, towards little investigated environmentally - appropriate technologies in areas that are of particular importance to least developing countries. Fellowships could be granted for the application of advanced R&D knowledge to traditional practices, funded by fiscal exemptions and other incentives;

iv. establishment of a special international fund to grant developing countries the auxiliary technology needed to monitor the state of their environment.

4. These initiatives could be coupled with a bold attack on the existing structural obstacles to the fulfilment of least developing countries technological needs. Developing countries are an heterogenous group and therefore their individual positions vary with respect to the nature and scope of the obstacles they face in acquiring, choosing, generating and adapting available technologies. Some countries have developed over the past two decades a sizeable science and technology system, an indigenous research and development capacity and a large industrial sector and are in a position to contribute substantially to the development of environmentally- appropriate technologies.

Checklist of Scientific and technological activities of relevance to environmental policies

A. INNOVATIONS PRESENTLY RESEARCHED

I. Resource-saving technologies

Agriculture and food production
- Upgraded agricultural methods and farming systems
- Biological pest control
- Upgraded storage
- Nitrogen fixation
- Bio-technologies for feedstock
- Aquaculture

Housing
- Construction materials
- Building design

Energy
- Saving technologies
- Renewable sources

Water sanitation
- Biological applications
- Water management systems

New product components
- Longer life-span materials
- Biodegradability and physico-chemical degradability
- Assembly of parts for recycling

II. Less pollution industrial technologies

Low-waste technologies

Treatment of waste
- Biological processes
- Chemical processes
- Physical processes
- Composite processes

III. Auxiliary technology

- Pollution monitoring equipment
- Bio-toxicology and epidemiology
- Natural resource monitoring equipment
- Metrology
- Storage of waste
- Biochips applications

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B. INNOVATIONS LITTLE INVESTIGATED AT PRESENT

Symbiotic soil-water, management (erosion and desertification)
Local stockbreeding, improved genetic resistance and efficiency
Forestry management and silviculture
Agricultural wastes biological conversion
Agricultural implements, tools, vehicles and equipment
Civil engineering
Transportation
Mining

Some Constraints arising from the Structure and Organisation of Research and Development Activities

1. It has been suggested that one of the main causes of the disappointing performance of the developing countries' research and development is that it basically imitates the structure and general principles of the developed countries' research and development. Two aspects are often critized: the choice of the subjects for research and the characteristics of the process of generation of technologies. Of course, some of the newly industrializing countries (Brazil, Mexico, India) have a sizable research and development establishment. Nevertheless, they tend to carrry out a research agenda which reflects the concern of industralised countries more than their own dilemma.

The Priorities for Research

2. The choice of a research subject is obviously important for the results of research on a new scientific and technological alternative. Developing countries are involved, to some extent, in the emergence of new technologies which are believed to have a favourable environmental impact: bio-technologies for agricultural,food, industrial and health applications; microelectronics; automation and robotics; material technologies; technologies for renewable energy. The integrated application of emerging and traditional technologies may provide a chance for a new type of innovation, as long as a thorough assessment is made of the potential consequences.

3. Industrializing countries with a sizable research and development system, such as India, Brazil, Egypt, Mexico, Argentina, the Philippines should carefully select their priorities for research and development. There may be technologies not worth competing for, for instance process technologies to produce a product that is already marketed. Brazil's technological and commercial success with ethanol technology is an illustration of this point: an oil-fuel substitute was obtained with a process that had been displaced and discarded, in developed countries, 35 years before.

4. The wide range of available technological options offers countries an opportunity to choose products and processes according to the function that these

technologies are to fulfil. Bio-technology is possibly the most promising innovation for the Third World because of its prospects for those that live on a biomass-based subsistence economy, and because its applications depend very much on the local physical and climatic characteristics and their biological resources. In order to work, the applications must be tailored to specific environmental conditions. Disillusion with bio-gas is often the consequence of not having recognized, at the design stage, that waste is a specific raw material in which the biological composition varies greatly, and which requires that the equipment be specifically adapted if it is to function efficiently. Research on a variety of microbiological applications (biological nitrogen-fixation, leaching and concentration of metals from low-grade mineral ores, biological pest control, indigenous fermented food preparations, agricultural wastes) should be given the right priority.

The Generation of Innovations

5. If the generation of technology is to make a significant impact on the rural world, the participation of the rural population (the actors and agents of innovation) should be obtained. The importance of this step is twofold: new production processes are not adopted simply as a new product, and the local population is the best source of traditional empirical knowledge with regard to the environment and to the locally proven technological solutions. Whenever the issue is the diffusion of known products (manual implements, simple equipment for transportation and storage), novel approaches may be implemented through a more adequate marketing organization (including product adaptation and maintenance).

6. The generation and diffusion of environmentally appropriate technologies meet various obstacles, examples of which are drawn from innovations in cleaner industrial technologies.

7. When the new process is not really a radical one, the innovation may be surrounded by a high degree of secrecy. If the innovation consists of a special way of exploiting a given equipment or operation, the technical change cannot be marketed and, therefore, it is poorly diffused. The traditional system of patents may deter the diffusion of this type of innovations.

8. Avoidance of product diversification among well-established industries may also partly explain the relatively larger diffusion of technologies for the recovery of energy from wastes generated in-plant. From the firm's point of view, this technical change is a substitution of cheaper inputs. End-of-pipe equipment is an attractive solution for this purpose.

9. Investments in environmentally appropriate technology are bound to be regarded by the firm, as a non-productive expenditure, as long as the treatment of pollutants is not part of the production process. Furthermore, whenever the firm is in a position to make separate decisions concerning its general production operations and end-of-pipe operations, it may tend to be careless about the capacity of the add-on equipments, its maintenance, and the environmental consequences of product (new waste) generated.

10. A thorough examination of obstacles on the way to the generation and diffusion of technologies is an important step to be considered in choosing a technology.

Possible International Initiatives to Promote Activities, in Education, Training and Communication

- Design of environment, technology and development courses for the curricula of social sciences, with particular attention paid to the higher education of economists and planners.

- Inclusion of environmentally appropriate technology in the curricula of industrial, civil, sanitation and forestry engineers, as well as agronomists.

- Refresher training courses for in-plant engineers on environmentally appropriate technology.

- Establishment of public oriented institutions (that can be modelled after the existing offices of technology assessment) for the public diffusion of scientific and technological knowledge and a wide debate on sensitive issues.

- Strenghtening of technical culture (world itinerant exhibitions, "Pullitzer" type of competition for scientific/environmental journalists).

Towards Decommercialization of Science and Technology

1. Many technologies pertain to the public domain, either because knowledge of their basic principles is widely spread and it can be reproduced given financial and intellectual resources, or because their term of registration has elapsed. If provided free or at basic cost, the availability of this public technology would be an incentive for local application: the cost of the environmentally-sound adaptation of such technology would be greatly reduced.

2. Basic research is today a process financed in most cases by public money. UNCTAD's strategy for the technological transformation of developing countries points out that "despite substantial government involvement and the public support of research and development, there are hardly any technological transactions in which the developing countries pay only the basic cost of the results of such R`& D, and do not have to bear in addition extra payments in the form of scarcity rent or monopoly profit charged by private owners of these results. The reason for this seems to be that the results of the publicly financed R`&`D have been placed under private ownership during the course of their being converted and embodied into some form of usable technology". Once a private organization (or a collective unit in the planned-economy countries) has commercialized the technology, it offers the results of basic R & D in a complex technology package from which it may be difficult to disentangle the originally embodied R & D which was generated by public means.

3. Governments of the developed countries have an important role to play in the process of decommercialization, i.e. ensuring that the technologies resulting from publicly financed R & D is transfered to developing countries on more reasonable terms. Research and technological developments carried out by public and multilateral organizations, or financed by public funds, as well as the results of such work, may be registered separately before they are packaged for use and subsequent sale. For example the World Health Organization has recently decided to obtain patents, or interest in patents, on patentable health technology developed through projects supported by it.

4. Given the growing importance of technologies based on biological processes - many of which have long been used in developing countries or are developed through the use of genetic stock from wild plants and animals - it is an additional reason to see that the results of research efforts, financed by the international community, revert freely and cheaply to developing countries which are the suppliers of an important component part of such new technologies. In the case of results from multilaterally-financed research, separate registration should be made a necessary practice, particularly when the R & D results contribute to enhance the environment, for humanity's common good.

A New Approach to Environmental Impact Assessment

1. The monitoring of technological impacts has been far from systematic ever since the size of development projects and industrial plants - growing in scale, number and location - should have demanded closer scrutiny. By the 50's, when impacts became more widely perceptible and some consideration was first given by economists and planners to the "externalities" of individual projects and industrial concerns, a backlog of scientific ignorance had accumulated, both with regard to the methodology of measuring and monitoring the effects on the environment, and with regard to the evaluation of such effects.

2. Environmental impact assessment, which rose in recent years as the standard methodology to measure impacts, derives from the economic concept of externalities. Many impact assessment statements and reports have been made recently, since formal assessment - particularly of industrial projects - became a prerequisite for funding and approval. Knowledge is building up in a number of sectorial activities, particularly in the more polluting industrial branches, as well as in open-pit mining, construction of dams and other large scale ventures. But answer to questions such as the scale of the transformations, the nature of cumulative factors, the reversible or irreversible nature of damage are still very much at a preliminary stage. Because of the nature of these studies, the fact that each project is a specific case study, the lessons of environmental impact studies do not generally lend themselves to generalizations. It is desirable and should be possible to evaluate this technique for policy recommendations.

3. Concern has also been expressed that environmental impact studies generally come too late into the planning process, when the project is already designed and considered feasible from a financial and economic point of view. It is also said to be a costly and delaying exercise. If environmental impact assessment is to be really integrated at an early planning and feasibility stage, costs of the preparatory work and delays of project implementation ought to be radically revised.

4. Two radically different variants to establish impact assessment are now being attempted: namely the "scoping process" approach which delimits the scope of the exercise in accordance with selected priorities (manpower, financial resources, etc.), and the technological impact assessment approach which enlarges the scope of scanning alternatives in accordance to the need which the project is to fulfil.

5. These two variants do not necessarily exclude each other because the first applies at the level of a project, while the second addresses to societal goals, and functions that must be performed if goals are to be reached. They are nevertheless widely opposed in the sense that a project has pre-determined functions that are difficult, if not impossible, to reverse once a specific project is chosen as the pathway to fulfil the selected function. The performance of technological impact assessment is a relatively new function of technological institutions. In some advance countries (USA, France), the issue is considered of such crucial importance for the future of society that the institutional mechanisms are designed so that the results of the assessment are publically debated. French and American offices of technological assessment are responsible to congress and parliament, respectively.

6. The methods, approaches, and results of environmental impact studies tend to illustrate that two kinds of impacts must be considered separately. The first is the impact of the technology itself. For instance, a new production process may generate less waste in terms of quantity, but, in terms of quality, waste may be more polluting or less treatable. A product may cause little contamination while being produced, but become a source of environmental hazards when discarded. The problems generated at this level can be tackled through increased R&D, engineering design, product change.

7. The second type of impact is linked to the thresholds peculiar to a given environment, i.e. the specific reactions that can be expected from a given ecosystem to the application of a given technology. Whenever a specific technology and methods of operation are applied to an ecosystem, thresholds will appear as a function of the characteristics of the receiving environment. For example, a number of "first generation" pollution problems were temporarily solved through the

relocation of activities to unspoilt "cleaner" sites. Less positive examples are provided by the current nitrification of underground water in many developed countries, the "sink-hole" effect of pumping underground water, the accumulation of tracemetals in the food-chain.

8. To deal with the problems of threshold, new planning instruments are needed to permit deciding which environmental conditions cannot sustain the impact of a given technology and which technology is best when a need, or a set of functions, are to be fulfiled, given a pattern of environmental and other constraints. For example, solar-cell technology may be fit when the need is energy for a low-powered equipment (transmition lines, for instance).

9. Finally, new ways must also be searched so that technological and environmental impact assessment may deal better with the time factor, the period that elapses between the initial build-up of a process and the moment the unforesee results, or effects, are perceived. The approach to the time factor appears more amenable when considering the life-span of a product which already exists. For instance, it is now acknowledged that the mealybug, a cassava pest newly-imported from Latin America, is spreading in West Africa at the rate of about 475 km per year; some hazardous susbstances stored in waste landfills persist in soils and underground water for over 500 years.

Towards an Assessment of Environmentally-Appropriate Technologies for Industry

1. There is growing realization that once a pollutant is generated, it can never be totally eliminated, whatever amount of technical or economic means are put into it. From the point of view of policies, it means moving from curative to preventive actions.

2. Recent trends of technological innovation in industry show that, with exceptions, the technology applied today to fight pollution is not a curative solution in the long-run. It may be called a "transfer" technology because it removes pollution from one media (generally air and surface water) only to transfer it to a more remote media (higher layers of the atmosphere, oceans, deeper layers of the ground).

3. In a number of cases, technology is applied to render waste less harmful (composting of municipal waste is an example), or to turn it into a more manageable physical state (sludge incineration, for instance). There are relatively few instances where technology transforms the physical, chemical and biological characteristics of the waste so as to recycle all the material components of waste. Consequently, the state of the technology re-inforces the view that preventive action must take over from cure.

4. The assessment of environmentally appropriate technologies developed so far is still at its initial stages and reflects the preponderance of innovations made in industry over all other sectors. The general perception is that the technology generated by industry in recent years falls into two large categories: the anti-pollution, end-of-pipe or add-on technology on the one hand; and the low-and-non waste technology, or cleaner technology on the other hand.

5. Anti-pollution technology (add-on or end-of-pipe technology) includes equipment and operations that either transfer pollution from one media to another (the filtering of gases contaminates water, the incineration of toxic solid waste generates polluting gases), or change the nature of the pollutant without making it less hazardous (polluted water is transformed into sludge).

6. Cleaner technology includes processes that may be similar to the above but that fulfil three different functions:

7. i. technology that prevents pollution to spread into any of the receiving media (air, water, land, food-chain); their environmental effect is to reduce the quantity of the pollutants generated, to change the quality of the pollutants by turning them less harmful, and to save energy and material inputs;

8. ii. technology that changes the composition or the design of the end-product in such a way that: the life-span of the product is extended which leads, over the years, to a global saving of energy and materials; the materials contained in the product favour its degradability by unsophisticated means (biodegradability of chemicals, for instance); the composition or the design of the product allows for partial or total recycling;

9. iii. technology's whose purpose is to monitor, measure, control and alert the occurence of an unforeseen and undesirable event; they often are a combination of precision instruments with computerized or automatic systems of information and alarm (metrology instrumentation, satellites, electronic monitoring equipment designed for hazardous plants).

10. To be operational, assessment of environmentally-appropriate technology should go beyond the step of classification towards the elaboration of a new assessment methodology. A number of structural changes at the government level, as well as the refocussing of the sectorial studies is needed. One of the advantages is to make more transparent the environmental impacts of technology, as well as the possible differential impact of process technology and product technology. Furthermore, it may serve as a basis to include other criteria, still undefined, concerning the environmental feedback of technology on society and development, i.e. technological and environmental risks, and thus provide guidelines for design of policy instruments for technical change.

Environmental and Technological Risks

1. In industrialized countries, the figures indicating the state of the air pollution, for instance, are not imbedded in average common knowledge to the extent that measurements of air temperature and humidity are. Rather, they are perceived visually, or through a number of indicators (odours, breathing), or people may be informed by the medias, but, often, the causes of illness and other discomforts are seldom acknowledged. The poorer people are the less they understand why their environment is affected. They may be quite capable of observing the change taking place, but the lack of educational opportunities, the absence of channels for them to feed information to decision-makers, or mere cultural differences, prevent them from making correlations between effects and causes.

2. It is generally recognized that environmental degradation affects social groups differently. World-wide, the vast majority of the people still live on a biomass-based subsistence economy: the basic maintenance of their life depends on their ability to make use of an environment which possesses qualities known to them and which they can manage with the technology available to them.

3. The rural population of the Third World offers many examples of the fragile relationship that exists between their traditional environment and their traditional technology. If, for any given reason, the environmental conditions are altered (more water in the streams), but the technology in use remains basically unchanged (slash-and-burn agriculture), the technology will become "inappropriate" to the new environmental conditions.

4. Development programmes in developing countries are often intended to fill the gap between old or traditional technology, and new environmental conditions, although the objectives of the programme are not explicitly stated in these terms. The problem which is rarely faced is that the old technology is the only one that the population masters. If the policy is to resettle a population, it is most likely that the old technology will be carried along, and create negative impacts, whenever the new site lacks the ecological conditions that were present before re-settlement became necessary. Unfortunately,

little is known about the process of generation, adoption and diffusion of technological innovations among populations that suffer from environmental disasters (natural or man-made).

5. Within countries, and more notably within cities, exposure to environmental risks varies greatly for different social groups. The location of dwellings next to hazardous industries is common place in the Third World (Mexico and Bhopal). The construction of slums on top of industrial dumpgrounds is possibly much more common than realised (Cubatao in Brazil). Risks in the industrial work environment may also be greater, both because regulations are not enforced and because the production processes are older, and are not equipped with the newly developed environmental monitoring technology. Access to drinking water and sanitation is another social indicator of environmental risk. Obviously not all environmental risks are a direct consequence of the environmental impact of technology. In many cases, it is the lack of technology that results in crowding, poor sanitary conditions, sheer poverty.

6. There is, however, some evidence that a number of technologies have a greater negative impact on the environment of the poor. A recent evaluation of the environmental impact of large dams concludes that there was a significant increase of water-borne diseases in the rural areas of Africa and Asia. The displacement and resettling of large numbers of people is costly in social and economic terms, and could also be in environmental terms. Social differences sharpen when new water is available for irrigation as a result of large water development schemes. Studies on pesticides in the Third World also make the point that it is the poorer groups in the population who are most affected by the side-effects of hazardous technologies, such as pesticides. Lesser-publicized technologies, often cited in health-related publications which involve products that are banned in their country of origin but are nevertheless exported to Third World countries; drugs, bottle feeding milk and a variety of chemical substances and hazardous wastes are some examples frequently quoted. A great deal of controversy is generally attached to the effects of hazardous products, either because the events occur in accidental circumstances, or because the accuracy of tests is questionned. A good information system on chemicals, wastes and other hazardous products is still to be achieved so that governments may appraise the risks and may be able to make accurate and informed choices.

7. The vulnerability of a society to environmental and technological risks is something that can and should be assessed. The first criteria is related to the site where the environmental impact occurs. The effects may be concentrated on and around the site but they can also migrate. Whereas the direct effects tend to be better known, the mechanisms of migration of pollutants or of potential hazards (for instance the depletion of a fish species by another) are not well understood. The second criteria is the income distribution structure. Income groups are affected differently by pollutants from well-identified sources, whose scale, frequency, intensity, potential risks are known. Higher income groups are more knowledgeable of the risk situation and may afford to avoid being in contact with the risk (home insulation, choice of residence, timing of travels, greater use of communication technologies, access to information and correct interpretation of the data). The last criteria is the spread of risks. Hazards that were once confined to the work environment are now diffused over the population at large, and even threaten future generations.

8. The characteristic of the environmental and technological risks to spread beyond their source has been slowly acknowledged in recent years, particularly in Europe and North America. It is generally understood to apply to air and water transboundary pollution. A more recent issue, the transfrontier movements of waste, also raises the question of spread of risks. But risk may stem from other causes, not only from the results of technology but also from its conception and operation. Failure of the production or emergency equipment in a plant is an example. Another cause may be the incorrect evaluation of the risks involved in the generation of a hazardous product or waste. Furthermore, a "cradle to grave" system of control is being established, in some industrialized countries, to monitor hazardous waste. But hazardous technologies (that generate toxic substances, for instance) are not presently monitored in a similar fashion. In this line, the UN general assembly recently called on the establishment of an international register of toxic substances.

9. Environmental and technological risks call for a new field of international cooperation. Some possible areas of common action are summarized:

i) creation of an internationally coordinated system to monitor hazardous technology, both with respect to spatially located activities (industries, known sources of pollution, natural resources depleting activities) and to transboundary transfer of equipment, process, methods of operation, products and waste;

ii) assessing the legal implications of environmental and technological risks, with particular reference to:
   a) ways of incorporating the notion of risks in current legal practice
   b) ways of inforcing made-to-measure technical prescriptions, instructions and norms of operations
   c) the liability of the generator of technology in relation to hazardous effects of its product.

iii) reforming the institutional framework and regulatory instruments to deal with the spread of environmental and technological risk;

iv) altering the system of funding environmental protection taking into account:

   a) the differential impact of add-on and cleaner technologies;
   b) the differential health benefits derived from the location of residence and place of work in relation to known sources of pollution;

v) enforcement of emergency planning - at the level of plants, neighbourhoods, and ecological zones (national and international) - to forecast risks arising both out of normal operations and accidental events;

vi) institutionalize research on the causes of environmental disasters and the means to prevent them.

New Technological Breakthroughs

1. Many new technologies have begun to emerge in the past 5 to 10 years. They are science-intensive, characterized by labour savings and in some cases, savings of raw materials, energy and waste. Some are applications of anciently-used biological principles (bio-technologies); others have been known since the 1950's and are recently commercialized (microelectronics). Others are even more recent developments (material technology; laser technology; space, marine and sea-bed technologies).

2. These technologies have varied and increasing applications in practically all sectors of economic activity. They are also creating new branches of activities (bio-electronics, telematics, transborder data flow of which remote sensing is a form); new products (computer-aided design, flexible manufacturing systems, industrial robots, single-cell proteins, fuel-grade alcohol; optical fibres; polymers; fine ceramics; made-to-measure materials) and new production systems (recombinant DNA techniques to improve crop and animal breeding methods; bacteria for oil recovery, for low-grade mining ores, for oxidation of non-toxic chemicals, for organic waste recovery).

3. From an environmental point of view, the following are the possible impacts of the newly emergent technologies:

Micro-electronic-based technologies

4. Monitoring and control functions are important for the development and diffusion of new products and systems of production:

   - environmental monitoring systems (pollution, floods, natural resources exploration and exploitation);

   - devices for irrigation, cattle and crop control;

   - automated production systems reduce material losses that occur through inefficient handling and less precise mechanical operations;

- closed circuit production systems (confinement systems) allow high-risk operations to take place on an industrial scale;

- computer-aided design devices reduce wastage of inputs (garment and textile industries);

- replacement by micro-electronic devices of mechanical component parts result in reduced consumption of certain raw materials (steel, aluminium) and the decreased weight and bulk of equipments.

5. Bio-technologies is the shorthand word for new knowledge and techniques derived from molecular biology, biochemistry, microbiological genetics and biochemical engineering sciences. It is believed that recent scientific discoveries will feed technological innovations for the next 30 years. They offer vast openings in three fields of environmental concern:

   - natural resources-saving techniques: new pharmaceutical and petrochemical products; fuels from biomass; bacterial oil recovery; extraction of oil from sandstone and limestone formations; microbial production of oil ..... and lubricants; bacterial extraction of mineral from low-grade ores.

   - techniques to enhance ecosystems: stress-resistant or "made-to-measure" crop varieties that withstand insects, diseases, heat, frost, wind and flooding; biological pest control; crops with extended growing seasons; genetically engineered nitrogen-fixation capacities; improved animal breeding.

   - waste treatment and materials recovery: bacterial treatment of oil spills; decomposition and detoxification of organic waste; single-cell proteins from agricultural wastes, pulp and paper waste, forest residues and agro-industrial by-products, for the production of animal feedstock.

   The wide-spread and uncontrolled diffusion of the emerging bio-technologies may give rise to increased risks: depletion of genetic resources; accidental breakdown of confined systems (particularly important in bio-technologies); possible virus regeneration in recombinant DNA, new professional hazards.

6. New materials:
Fine ceramics, optical fibres and plastic material share the characteristic of being lighter, less bulky and more resistant than the materials they replace. They involve global savings of raw materials (inputs from non-renewable resources such as steel, petrochemicals, copper) and the use of waste products (sands, agricultural and wood waste, rubber and plastic wastes as fillers in plastic materials). Their greater resistance is an advantage because it reduces their rate of obsolescence but it may be an inconvenient for recycling and recovery.