UNITED NATIONS

E

Economic and Social Council

Distr.
GENERAL

E/C.7/1996/11
23 April 1996

ORIGINAL: ENGLISH

COMMITTEE ON NATURAL RESOURCES
Third session
6-17 May 1996
Item 11 of the provisional agenda*

INTEGRATION OF THE ISSUE OF THE SUSTAINABLE SUPPLY OF MINERALS INTO THE UNITED NATIONS PROCESSES FOR ADDRESSING AGENDA 21

Towards the sustainable supply of minerals in the context of Agenda 21

Inter-sessional strategy paper of the Committee on Natural Resources

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96-09696 (E) 300496 020596

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INTRODUCTION

1. The Committee on Natural Resources has expressed its concern that minerals issues, notably issues of the sustainable supply of mineral resources, have received little explicit attention in Agenda 21. 1/ Minerals issues include issues of the continuing availability of mineral resources, as determined by the global endowment and by restrictions on access to that endowment, as well as issues that affect the demand for mineral resources, such as the environmental impacts of minerals use, the efficiency of minerals use, recycling and substitution, all of which are linked by the concept of sustainable consumption patterns.

2. The spectacular technological and economic development and resulting population growth of the nineteenth and twentieth centuries was made possible by the expansion of the use of all kinds of natural resources, above all petroleum and mineral resources. Such resources are the foundation of the energy, manufacturing, communication and construction industries, 2/ and are also the foundation of modern agricultural industry because of its dependence on mechanization, fertilizers, herbicides and pesticides; the level of their consumption of these resources continues to increase.

3. There is a continuing divergence of opinion concerning the long-term availability of mineral resources, due partly to the time-scales being considered, partly to a real lack of knowledge of resource potential (and of recycling potential), and partly to the difficulty of predicting future demand in the context of technological change and possible future substitution of both materials and energy sources. Accordingly, the current emphasis should be on improving global management strategies for the optimal and most efficient supply and use of available resources with minimum environmental impact.

4. The Brundtland report 3/ recognized the special management problems that are being posed for sustainable development by the depletion of non-living resources; it stated that the rate of depletion should take into account the criticality of a given resource, the availability of technologies for minimizing depletion and the likelihood of substitutes being available. Thus, land should not be degraded beyond reasonable recovery. It is especially important that, for minerals and fossil fuels, the rate of depletion and the emphasis on recycling and economy of use be calibrated to ensure that the resource does not run out before acceptable substitutes are available. Sustainable development requires that the rate of depletion of non-renewable resources foreclose as few future options as possible.

5. In recent decades, the concern that the availability of resources would set limits to national or global economic growth has been largely displaced by the more immediate concern that limits are being set by the environmental impacts of the increasing human population and its increasing consumption of resources. Land degradation, scarcity of water and pollution of air and water are perhaps the most pressing problems, but the issue that has captured the greatest attention from Governments has been that of global warming arising from greenhouse gases, in particular from carbon dioxide emissions. The pressure to move away from fossil fuels towards renewable (and nuclear) energy sources is

due more to the evidence of environmental impacts than to any recognition of the clearly finite limits of petroleum supply or of the desirability of conserving this valuable chemical material feedstock for purposes other than energy. Similar environmental concerns are modifying consumption patterns and moderating demand for a number of metallic mineral commodities.

6. At the United Nations Conference on Environment and Development (UNCED), Agenda 21 was developed to address the pressing problems of today and to prepare the world for the challenges of the next century (para. 1.3). The Commission on Sustainable Development was established to promote the implementation of Agenda 21, and has called for the establishment of indicators of sustainable development to help assess progress.

7. The main work on such indicators relates to the capacity of the global environment to absorb the environmental impacts of human activities: usually based on the so-called pressure, state, response model, they are still relatively undeveloped compared to traditional economic and social indicators. 4/ Moreover, environmental impacts are themselves closely related to the increasing use of mineral, energy and water resources, and there is a complementary need for indicators that take account of non-renewable 5/ resources.

8. Agenda 21 also called for identification of balanced patterns of consumption worldwide that the Earth can support in the long term (para. 10 (e)). The concept of sustainable consumption patterns carries with it the concept of sustainable production patterns, and is usually considered in terms of the environmental impacts that provide the short-term constraint. It is recognized, for example, that the major cause of the deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in industrialized countries (para. 4.3). But it is also necessary that the supply be sustainable for as long as required, which in the longer term may become the critical constraint.

9. Ultimately, the global goal must be to devise models for a relatively steady-state society, in which population size is in broad balance with the availability of resources. 6/ The general nature of the problem is well understood, and it is recognized that continuing efforts must be made to encourage greater efficiency and minimize waste. A paper prepared by the Economic Commission for Europe recognizes that the changes in production and consumption patterns to meet the criteria for sustainable development will require action in all fields of economic and social activity, but also suggests that first of all, a proper definition of sustainable consumption should be laid down in a charter. 7/

10. Clearly, as foreshadowed in the Brundtland report, the definition of sustainable consumption patterns must take into account key minerals issues: the capacity of the environment to absorb the effects of resource use, the sustainability of the supply of essentially non-renewable resources, and the possibilities for modifying production and consumption patterns through greater efficiency of use, new technologies, recycling and substitution.

11. Increasing concerns about the environmental impacts of the exploitation, extraction and use of minerals are also leading to economic or sociopolitical constraints on the capacity to meet demand, which is also being reduced more generally by competing land uses as the global population increases. The competition for land use is likely to close additional areas to exploration and development, as it has already done in parts of Europe and the United States of America.

12. It is therefore especially important that issues of mineral supply be considered as part of the approach proposed in Agenda 21, chapter 10 (Integrated approach to the planning and management of land resources). It is recognized in general terms that integration should take place on two levels, considering, on the one hand, all environmental, social and economic factors (including, for example, impacts of the various economic and social sectors on the environment and natural resources) and on the other, all environmental and resource components together (i.e., air, water, biota, land, geological and natural resources) (para. 10.3).

13. However, there is a general tendency to exclude mineral resources from discussion of both land and natural resources, and minerals issues receive little specific attention in Agenda 21, or in follow-up activities (see E/CN.17/1995/2). Notably, there is no chapter in Agenda 21 dealing with the minerals sector, as there is for other sectors, such as agriculture (chap. 14); the present paper attempts to redress that imbalance. It is based on the belief that understanding of the key minerals issues can provide greater coherence to the implementation of Agenda 21, and that such issues have particular importance for developing countries and economies in transition.

Scope of this paper

14. In the context outlined above, the present strategy paper has limited objectives. It aims first to emphasize the key importance of mineral resources for sustainable development and quality of life and, as a consequence, to identify simple low-cost actions at the international level. These will provide new information links to improve the basis for global planning and management strategies, integrating environmental and development concerns.

15. In addition to the goal of an environmentally stable future that is embodied in the Rio Declaration on Environment and Development, 8/ most explicitly in its Principle 7, the United Nations has the parallel goal of improving the living standards in less developed countries (Principles 5 and 6). The United Nations has long attempted to assist developing countries in the development of their mineral resources as a means to implement those principles. It is proposed to discuss the special problems of minerals-producing countries, particularly less developed countries, in a subsequent strategy paper of the Commission on Sustainable Development. However, the international actions proposed in the present paper should also be of particular value to such countries.

16. The present paper discusses both metallic and industrial minerals but not the fuel minerals. 9/ For reasons indicated in the text, the recommendations have particular relevance to the metallic minerals.

17. The main minerals issues identified above require consideration of the whole mineral cycle, from mineral exploration and discovery through extraction, processing, manufacture and utilization to eventual recovery or disposal. Some downstream aspects of that cycle related to waste disposal and pollution are addressed in Agenda 21, chapters 19 (Environmentally sound management of toxic wastes) and 20 (Environmentally sound management of hazardous wastes), and there are many existing projects in this field. 10/ The present paper therefore focuses on aspects of the cycle that bear more directly on the sustainable supply of mineral resources and sustainable consumption patterns, such as efficiency of extraction and use, recycling, new technologies and substitution, all of which are driven at least in part by concern over environmental impacts, and all of which lead to reduction in the rate of increase of the overall demand.

18. The management of mineral resources requires cooperation between private industry and Governments (and other stakeholders) at various levels. In recent decades, exploration for metallic mineral resources has been increasingly dominated by international mining companies with the resources and expertise to find and develop world-class deposits (thus following the earlier trend in the petroleum industry). As a result, the development of such mineral resources is very largely a matter for private industry under the overall control of national Governments and local governments in accordance with Principle 2 of the Rio Declaration on Environment and Development.

19. The recommendations in the present paper are developed in full cognizance of the role played by the international mining industry in the efficient exploration for and development of global mineral resources. They are therefore designed to complement that role within the overall global partnership for sustainable development. Indeed, the actions proposed here will also be of value to the international mining industry in providing an improved knowledge base for exploration and development strategies. They are also complementary to the approach taken by the International Conference on Development, Environment and Mining. 11/ That Conference gave particular attention to public and private sector roles in relation to mining and its environmental impacts, with emphasis on the role of national Governments.

20. The key minerals issues are being addressed with increasing effectiveness at the national and regional levels. But they are ultimately global issues, and their analysis also needs to be undertaken on a global scale. Such analysis, through a global partnership, will also allow a more realistic assessment of the management strategies that are required at the national and regional levels. It is therefore suggested here that the United Nations has a critical role to play in coordinating and integrating information on key minerals issues on a global scale, in accordance with the principles set out in Agenda 21, especially chapter 35 (Science for sustainable development), chapter 37 (National mechanisms and international cooperation for capacity-building in developing countries), and chapter 40 (Information for decision-making).

21. It is recognized in chapter 8 of Agenda 21 (Integrating environment and development in decision-making) that a first step towards the integration of sustainability into economic management is the establishment of better measurement of the crucial role of the environment as a source of natural

capital and as a sink for by-products generated during the production of man-made capital and other human activities (para. 8.41). This natural capital must include the endowment of minerals of all kinds, and one aim of the present paper is to assist in that first step by identifying means for the better measurement of such parameters with respect to minerals.

22. At present, there are important gaps in the global knowledge base; the present paper therefore attempts to define some of the gaps and suggest possible approaches to filling them. It is also suggested that such knowledge gaps can be filled at relatively very low cost by building on existing efforts of many institutions at the national and regional levels.

23. The key minerals issues are also linked by the overriding issue of global population growth. Accordingly, some aspects of the relationship between population, resource use and the environment are discussed below prior to further discussion of the factors that mitigate the effects of resource use or affect the availability of resources.

I. POPULATION GROWTH AND INCREASING DEMAND

24. Global population will almost certainly reach 8 billion over the next 30 to 40 years, and is unlikely to stabilize much below 12 billion before the end of the twenty-first century. 12/ At the same time, efforts must be made to improve living standards in less developed countries. In the absence of major steps towards dematerialization, the demand for materials and energy will continue to increase due to both rapidly increasing population levels and aspirations for improved living standards. There will also be enormous additional burdens on the natural environment due to increasing consumption.

25. The Brundtland report considered that global economic expansion by a factor of 5 to 10 would be required in order to meet the demand for improved living standards for an increasing population. It was apparently believed that such growth could be achieved largely by a more efficient use of materials and energy, as well as by improved technology to reduce environmental impacts.

26. However, there has since been an attempt to distinguish between economic growth, which involves increased inputs of energy and materials, and economic development, which can take place through increased efficiency without increased consumption of material capital. 13/ From that standpoint, it has been suggested that the Brundtland report is too optimistic: an increase by a factor of 5 to 10 cannot come from development alone, and if it comes mainly from growth it will be devastatingly unsustainable. 12/

27. There has been significant decoupling of economic expansion from metallic minerals consumption in developed countries in recent decades. The intensity of use of aluminium, for example (measured in kilograms (kgs) per millions of dollars of gross national product (GNP)), has declined since 1975. 14/ Substitution by non-metallic materials, combined with efficiencies in the use of the metals, partly accounts for the lower intensity of use of metals in industrialized countries. Another contributing factor is the great increase in value-adding in finished products. But although the relative importance of

metals has declined in industrial economies, there has not been significant decline in the absolute quantities of metals used, i.e., there has not been an overall dematerialization. 15/

28. Globally, consumption continues to increase; although demand for some minerals has stabilized, and is even declining in some developed countries, this will be more than offset by increasing demand in developing countries and areas, particularly in South-East Asia, where population is also growing rapidly. For example, per capita consumption in the newly industrializing Republic of Korea and Taiwan Province of China has grown rapidly over the last 30 years to levels similar to those of the industrialized countries. Recent analyses 16/ also show that between 1950 and 1990, the population in underdeveloped regions grew from 68 to 77 per cent of the global population, while the share of consumption of various metals grew from between 1 and 5 per cent to between 12 and 25 per cent.

29. For similar reasons, it seems likely that the demand for fuel minerals will continue to increase for several decades. 17/ However, the demand for energy has continued to increase in the developed as well as the developing countries. Such increased materials and energy use will inevitably be accompanied by increased environmental impacts.

30. Population, resource use and the environment can also be clearly linked through the concepts of per capita use of resources and per capita use of space. The total impact of the human population is the product of population and per capita resource use, 18/ and it can be controlled by controlling either or both.

A. The support square

31. The per capita use of space is defined by the total available area divided by the total population and has been called the support square, which has been described as the scrap of land that must supply all the resources that an individual uses throughout a life, and that must fulfil the same purpose for others who follow. Somehow, that space must also consume most of the solid wastes left over. 19/ This anthropogenic concept actually overstates the area available per capita, since the need to preserve areas of natural environment and biodiversity must also be recognized: the same total area must support most other land-based species as well as the human population.

32. Nevertheless, the diminishing size of the support square gives a very graphic illustration of the impact of the increasing human population (see figure 1). The average global support square towards the end of the next century is likely to be about 100 metres square, about the same as the local support square for Europe today. But Europe offers a particularly favourable environment for human habitation. Moreover, like other developed countries in North America and Asia, European countries are not wholly dependent on the local support square: they obtain a substantial part of their resources from other less densely populated regions.

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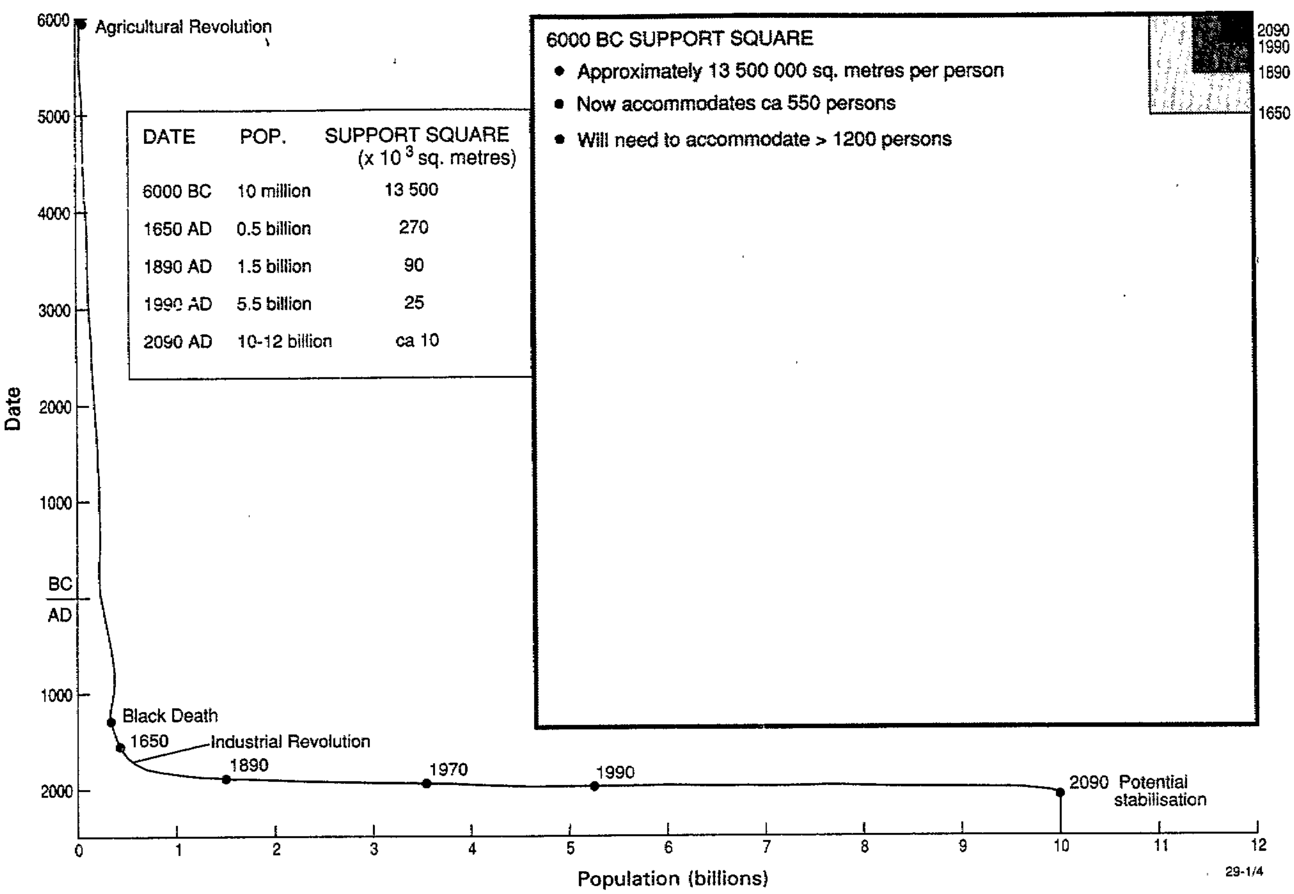
Figure 1. Growth in global population and resulting shrinkage in the global support square



33. To a considerable extent, therefore, environmental impacts associated with the production of both renewable and non-renewable resources are also borne elsewhere. As the global population increases with its attendant environmental impacts, pressures on land use will also increase, as will pressures on the natural environment and on biodiversity. The expanding densely populated regions will place increasing pressure on the shrinking less densely populated regions to supply resources, and it will become increasingly difficult to guarantee external supplies of both renewable and non-renewable resources. It will be increasingly necessary to recognize mineral supply as a global issue that requires global management strategies (see sect. III below).

B. Per capita resource use

34. The average per capita consumption of all minerals has been estimated at close to 10 tons per annum. The total impact for the global population involves the displacement of about 50 billion tons of minerals per annum, a figure substantially greater than the amount of material moved by natural processes. A large proportion of this material consists of industrial minerals, which are relocated from quarries to the sites of growing cities and to transport networks.

35. In the major industrial countries, consumption is much higher than the global average. In Germany, for example, it has been estimated that the average individual, in a lifetime of 70 years, consumes about 772 tons of construction materials, nearly 54 tons of other industrial minerals, about 363 tons of fuel minerals and about 43 tons of metals, mainly steel. 20/ Allowing for the quantities of ore and overburden that are involved in producing the final products, it is likely that some 1,600 tons of rock are consumed by each individual, or well over 20 tons per annum. A wider analysis of material flows in Germany arrived at a figure of 33 tons per capita per annum, excluding water and air consumption, or 1 kg per deutsche mark of gross domestic product (GDP). 21/

36. The volume of rock involved over the average lifetime is more than 500 cubic metres, which corresponds to an area more than 7 metres square excavated to a depth of 10 metres, approximately 0.5 per cent of the 100 metre support square.

37. If consumption on that scale were extended to a population of 10 to 12 billion, the total impact would be more than quadrupled to over 200 billion tons, or approaching 100 cubic kilometres of rock each year. It is hardly possible to argue that such consumption rates are sustainable, either in terms of their environmental impact or in terms of the availability of resources.

38. This discussion serves to illustrate the unsustainability of present demand trends and the consumption patterns that cause them. Clearly, every effort must be made to decouple economic expansion as far as possible from increased use of materials and energy. Targets for sustainable consumption patterns will need to be set in the light of the best possible knowledge of the impact of resource use (see sect. II below) and of the availability of resources (see sect. IV below).

II. TOWARDS SUSTAINABLE CONSUMPTION PATTERNS: MITIGATION OF THE IMPACTS OF RESOURCE USE

39. As noted above, the factors that moderate demand for minerals from primary sources, notably increased efficiency of extraction and use, recycling and substitution, are driven at least in part by concern over environmental impacts, although normal market forces also operate. Those factors are therefore considered below in terms of the directions of change in consumption patterns that environmental impacts may dictate.

A. Environmental impacts of minerals use and response strategies

40. The current relationships among atmosphere, hydrosphere, lithosphere and biosphere are the result of evolution throughout Earth history. The interactions are complex, but rates of change resulting from natural above-ground or exogenic processes are relatively slow on human time-scales, and the natural environment is in a state of dynamic quasi-equilibrium. Soils, in particular, form part of an oxidized zone resulting from interaction between bedrock, air, water, plants and animals.

41. The environmental impacts of minerals extraction and use arise from the disturbance of the natural balance of earth processes. In the case of phosphate, for example, phosphate that has been sequestered by natural exogenic processes over hundreds of millions of years is being returned to the land surface on a time-scale of a few hundreds of years.

42. Metallic ore deposits, in contrast, are largely formed by subsurface or endogenic processes, and are unusual concentrations of elements that normally have very low concentrations in soils and water. The ores are largely derived from below the oxidized zone, which is broadly in equilibrium with air and groundwater. Both natural weathering and mineral processing therefore involve the oxidation of mineral ores and the release of various pollutants, including sulphur dioxide and toxic trace elements.

1. Metallic minerals

43. One of the major impacts of the use of metallic minerals arises from the energy used in their production: the timing and nature of any changes made in the energy mix will have major implications for the mineral industry as a whole. Gases released in the production process, notably sulphur dioxide, also cause environmental problems, such as acid rain, and are important in climate change analyses. A number of the metals also have an intrinsic toxicity, so that they can cause unacceptable pollution (as with lead in petrol).

44. The International Council on Metals and the Environment (ICME) has been established by the international mining industry to promote sound environmental and health policies and practices in the production, use, recycling and disposal of non-ferrous and precious metals. It has cooperated with the organizations and bodies of the United Nations system, including the United Nations Conference on Trade and Development (UNCTAD), the United Nations Environment Programme (UNEP) and the Department for Development Support and Management Services of the United Nations Secretariat, as well as with other international bodies, such as the Organisation for Economic Cooperation and Development (OECD). More generally, the environment has become a core business issue, as ecological and economic factors are merged into the practice of business management, 22/ and much technological progress is being driven by market forces.

2. Efficiency of minerals use and impact mitigation

45. The ideal industrial ecosystem would have a minimal input of primary materials, including metals. Inputs can be reduced by more efficient processing throughout the cycle, by reduction of waste and by recycling. For example, in 1994, reclaimed metals and mineral materials in the United States of America accounted for about one quarter of the total mineral raw materials used. 23/ For specific metals, such as lead and copper, recycled material may account for well over half the total consumption in industrialized countries. Recycling trends are being monitored by various national organizations and ICME has commissioned a study on the recycling of non-ferrous metals and its benefits, issues and trends.

46. Environmental impacts can be further reduced by improved treatment of waste, and where necessary and possible, by substitution. For example, there may be an opportunity to use waste materials from the production of high-value commodities to substitute for primary raw materials in the production of low-value commodities, as in the use of fly ash derived from the production of electricity based on coal as a substitute for primary raw materials for cement production.

47. There has been increasing substitution for metals by new materials and composites. 24/ Some of these, such as ceramic materials, inorganic glasses and optical fibre, are derived from relatively common rock-forming minerals, while others, notably plastics, depend on the supply of the fuel minerals; relatively few are derived from renewable materials. In general, therefore, substitution involves replacing one non-renewable resource by another. It does not contribute substantially to dematerialization, although it may contribute substantially to the reduction of environmental impacts.

48. One reason for substitution of metals for some purposes is that less energy is required for their production (for example, for the production of paper and plastic products) than is required for equivalent metallic products. However, the differences are not so large as to overcome other factors, such as specific properties and processability for particular purposes. There have also been great improvements in the energy efficiency of primary production and forming of metals, and further improvements are possible.

49. Some attempts have been made to assess the environmental impact of extraction and processing involved in the primary production of metals. For example, a pilot study of mass balances (inputs and outputs) in the production of nickel has been undertaken in Germany. 25/ The study took into account the different flows involved in the processing of laterite ores of various types and sulphide ores. The quantitative information obtained from such studies could be used in assessing the total environmental impacts of alternative source materials.

50. Attempts are also being made to assess the environmental impacts of the production of various goods by focusing on material inputs and taking into account all phases of product life-cycles, notably at the Wuppertal Institute. It is postulated that the totality of all life-cycle material movements, including the materials consumed for the provision of transportation and energy,

serves as a proxy for the environmental impact potential of goods. 26/ It is therefore proposed to classify products according to material input per service unit. The main aim is to assist in overall dematerialization strategy by developing eco-efficient service concepts, through which service unit output is increased while material input remains constant or is decreased. Clearly, general reductions in material inputs, including energy materials, would also lead to general reductions in waste and in any toxic chemical flows.

51. It seems likely, however, that the main approach to environmental impacts related to metallic minerals will continue to be through addressing the problems of particular identified adverse outputs from the industrial ecosystem. Agenda 21, for example, deals specifically with the environmentally sound management of toxic chemicals in chapter 19, of hazardous wastes in chapter 20, and of solid wastes and sewage-related issues in chapter 21. Nevertheless, such strategies will be more effective if it is recognized that those outputs are specifically related to material inputs that may themselves be subject to modification. In considering alternative material inputs, knowledge of any eco-toxicity of products throughout the life-cycles of the alternatives must be considered, and there is a need to promote careful management to minimize potential impacts. Remedial measures may therefore be possible at all stages in the product life-cycle.

52. ICME has paid particular attention to the methodology of risk assessment. Work has been undertaken to describe metals and their toxicities, and to provide an overview of current methodologies and related biases.

53. The need for baseline studies against which to assess environmental impacts is discussed in section II.B below.

3. Industrial minerals

54. In the context of land-use planning, it is clearly important to take particular note of the demand for industrial minerals, which as noted above form the dominant component of total material usage. Debate about the depletion of mineral resources has been mainly concerned with the metallic and fuel minerals, with the implicit assumption that supplies of industrial minerals are inexhaustible. However, because of the enormous quantities involved and because they are not readily recycled, the supply of industrial minerals raises particular problems of environmental impacts.

55. It might be supposed that once the main infrastructure of industrialized countries has been established, the need for construction materials (for replacement and maintenance) would be significantly reduced, thus contributing to the process of dematerialization. 27/ Apparently, however, this stage has not yet been reached in Europe. Although population there has stabilized, the annual consumption of construction materials continues to increase, and there is widespread concern about the environmental impacts of quarrying and transport. 28/ To meet the demand, there has also been an increase in the amount of sand and gravel derived from shallow offshore areas, and coastal superquarries have also been developed. Indeed, it has been suggested that sustainable development of the coastal zone may require imposition of a littoral

or thalassic tax that, like a carbon tax, takes a global view of the "polluter pays" principle. 29/

56. Thus, the rate of consumption of construction materials and the environmental impacts of such consumption are clearly important issues for the promotion of sustainable construction industry activities (see Agenda 21, chap. 7G).

57. Among industrial minerals, phosphate has a special importance because of its essential contribution to the productivity of the agricultural industry. 30/ Phosphate production increased roughly sixfold between 1950 and 1980 to about 150 million tons per annum (roughly 30 kg per capita globally and almost 50 kg per capita in some countries). Phosphate production has fallen recently because of the near collapse of output from the former USSR but is likely to continue to rise in the future to meet the needs of the growing global population. Reserves are very large 31/ but are clearly finite and unevenly distributed. As is the case for petroleum, however, the principal concern is the environmental impacts of phosphate use that result from the greatly increased levels of phosphate, especially in inland waters. But there is no substitute, and it is difficult to control and reduce consumption.

4. Technical assessment of impact mitigation and changing demand

58. Under the heading of "International cooperation and coordination", Agenda 21 suggested that reviewing the role and impact of unsustainable production and consumption patterns and lifestyles and their relation to sustainable development should be given high priority (paras. 4.12 and 4.13).

59. At its third session, the Commission on Sustainable Development noted the initiative taken by the Government of Norway in hosting the Oslo Round-table Conference on Sustainable Production and Consumption (6-10 February 1995) and its contribution to underlining the importance of focusing on demand-side issues as a complement to the traditional supply-side approach.

60. The Commission also called for intensified efforts to reduce the energy and material intensities of production and consumption through improving energy efficiency, taking energy-saving measures, technological innovations and transfer, increased waste recovery, and reusing and recycling of materials, and it noted the value of the life-cycle approach in assessing environmental impacts.

B. Monitoring the mineral cycle

61. In so far as they fall within its mandate, UNCTAD has addressed aspects of the issues discussed above and noted by the Commission. For example, it has considered standards and regulations relating to process and production methods, and it has also considered environmentally friendly products and eco-labelling in the context of international trade (see E/1994/47). Some relevant work has also been undertaken by the United Nations Industrial Development Organization (UNIDO) and UNEP.

62. However, there appears to be no standing United Nations body that is concerned with the technical aspects of materials and energy use in the industrial ecosystem. Much work in this area is currently being carried out in the industrial countries, 32/ but there appears to be no provision for systematic and continuing analysis of such research at the global level that could provide ongoing assessments of the technological progress being made towards sustainable resource use, i.e., of the potential of improved efficiency, recycling, new materials technology and substitution for reducing material and energy inputs and minimizing undesirable outputs (wastes).

63. Such analysis would be valuable in encouraging world best practice in the mitigation of environmental impacts, both in industrialized and developing countries, and would also be of great value in assessing future demand for primary material and energy inputs to the industrial ecosystem.

64. The work could be carried out by an appropriately constituted United Nations technical commission. The Commission for Hydrology of the World Meteorological Organization (WMO) provides a general model of such a commission, although there is no parent body in the minerals area corresponding to WMO. The expertise for a commission for materials would be drawn essentially from the engineering and materials science disciplines, and would provide a high-level body in the United Nations for input from the technological sciences and engineering.

65. In addition, the scope of such a commission could be broadened to cover the issues relating to availability of resources (which are considered in sect. III below), as well as expertise in the areas of geology resource assessment and mining engineering, and would provide an appropriate technical link to bodies concerned with the mining sector, including ICME.

Recommendation 1

66. It is therefore recommended that a commission on mining and materials be established to assess and report on technological progress towards the sustainable use of resources through improved efficiency, new technologies, substitution and recycling.

67. The mandate of the proposed commission should include the compilation of information on the total impacts of the use of various commodities as an essential basis for determining optimum consumption patterns. This would involve an assessment of mass balances in the use of commodities, as well as the assessment of material inputs per unit of service, and would also provide input to the assessment of future demand.

68. In addition, such a commission could assist the United Nations in identifying opportunities (e.g., in extractive metallurgy technology) in its capacity-building programmes for technology transfer to non-OECD countries.

69. The mandate should also include the study of the technology of resource discovery and extraction, trends in the efficiency and cost of new mineral resources, and trends in recycling.

C. Monitoring the terrestrial environment

70. Because natural processes and human activities are continuously modifying the chemical composition of the environment, it is necessary to monitor the health of the surface of the solid earth in the same way as the health of the oceans and atmosphere are being monitored. The natural concentration of chemical elements reflects the variability of the geology, and knowledge of the natural variation can be critical in assessing pollution at all scales resulting from any stage of the mineral cycle.

71. The final report of the International Geochemical Mapping Project of the International Geological Correlation Program 33/ has addressed the need for a coherent, systematic, worldwide, multi-element geochemical database, and has made a comprehensive analysis of the basic requirements and likely costs.

72. The report points out that such a database is pertinent to the administrative and legal issues that are involved in the sustainable long-term management of environmental and mineral resources, and contains information that is directly relevant to economic and environmental decisions involving mineral exploration, extraction and processing; manufacturing industries; agriculture; forestry; many aspects of human and animal health; waste disposal; and land-use planning. It has been established that available data are substantially incomplete and internally inconsistent. Evidently, the data required could be obtained by enlisting the cooperation of national geological surveys. The necessary central coordination could be carried out by an appropriate United Nations agency. Such a global geochemical database would complement and enhance the value of other data sets, such as the Land Data project using Advanced Very High Resolution Radiometer (AVHRR) data.

Recommendation 2

73. It is therefore recommended that a programme to produce a global geochemical database be implemented, as identified and evaluated by the International Geochemical Mapping Project of the International Geological Correlation Program, in order to provide an essential contribution to objective and effective environmental and resource management.

74. It has been estimated that full data acquisition will require a minimum of a decade. Given the immediate relevance of such data to intensifying land-use problems, the programme should be initiated without delay. Central coordination will be necessary for the duration of the programme, and progress should be expedited and facilitated by a small technical secretariat, funded and administered through a recognized international organization. Individual countries should be encouraged to support and participate in the work.

III. TOWARDS SUSTAINABLE CONSUMPTION PATTERNS: AVAILABILITY OF RESOURCES

A. General outlook

75. The supply of mineral resources is essentially a response to demand that has largely been regulated by the price mechanism. Because of the success of the mineral industry in meeting demand in recent decades, there has been plentiful and low-cost supply, stimulating consumption and therefore demand. That situation was temporarily changed by the oil price shocks of the 1970s. In general, as discussed in sections I and II above, levels of demand do change through time, not only as a result of changes in cost but also because of substitution, recycling, technological advances or environmental concerns. It is necessary to consider, however, whether the resulting production and consumption patterns are also sustainable in terms of availability of resources.

76. Current knowledge of the future availability of resources (and therefore of whether production and consumption patterns are sustainable) is based essentially on the assessments of identified resources, which are not readily related to prospective mineral provinces or to longer term mineral potential. It is clear from these assessments, however (see sect. III.B below), that the supply of mineral and petroleum resources over time-scales of a few decades is well assured. The trend towards the internationalization of major resource companies, allied with increasingly effective exploration methodologies, has permitted the ready maintenance of the world's stock of economic identified resources. Technological advances in mining methods and mineral processing (e.g., for gold and copper) and strong competition have also resulted in stable or declining deflated commodity prices. 34/

77. Available information on identified resources, however, does not provide an assurance of supply over the longer time-scales of sustainable development as far as the potential stabilization of the global population at the end of the next century or the potential development of a steady-state further in the future.

78. The evident continuing success in meeting demand, however, must be set against the relatively short period that has elapsed since the industrial revolution, when such resources first began to be exploited on a large scale, as well as the current exponential growth in demand. Mineral resources are essentially non-renewable, and the economic resource potential has been severely depleted during the twentieth century at an ever increasing rate. There is no doubt that there are real limits to the availability of ore deposits of the kinds and grades currently being mined: the trend towards utilization of lower-grade ores is already well-established.

79. The issues involved in assessing the sustainability of mineral supply in the long term have been comprehensively addressed in the scientific literature but have received little explicit attention in Agenda 21 or the more general debate on sustainability. There has been a tendency to take either too pessimistic a view, using published figures of ore reserves, or too optimistic a view, on the basis that mineral resources are essentially infinite and that

economically benign solutions will be found to the technological problems when scarcities of conventional mineral deposits emerge.

80. In the very long term, it is hardly possible to predict how far technological advances or specific scarcities will lead to reduced demand (dematerialization) or successful substitution (especially of energy), by renewable resources. Eventually, the development of non-polluting energy sources may largely solve the problems of resource supply by allowing the extraction of minerals from sources that cannot at present be exploited economically without unacceptable environmental impacts, but the time-scale of any such development is very uncertain.

81. Meanwhile, usage continues at rates that are not sustainable in the long term. During the period of increasing global population and increasing demand for mineral resources, it is prudent to be well informed of constraints on the future availability of mineral resources. Current knowledge of the global potential for discovering new deposits is very limited, and this deficiency must be addressed. There are also increasing pressures on land use, which may make it increasingly difficult to explore for and develop available resources. The above-mentioned issues are discussed below. It is not a question of running out of resources but of avoiding potential problems and ensuring the optimum and efficient use of available resources with minimum environmental impact.

B. The horizon of sustainability: identified and undiscovered resources

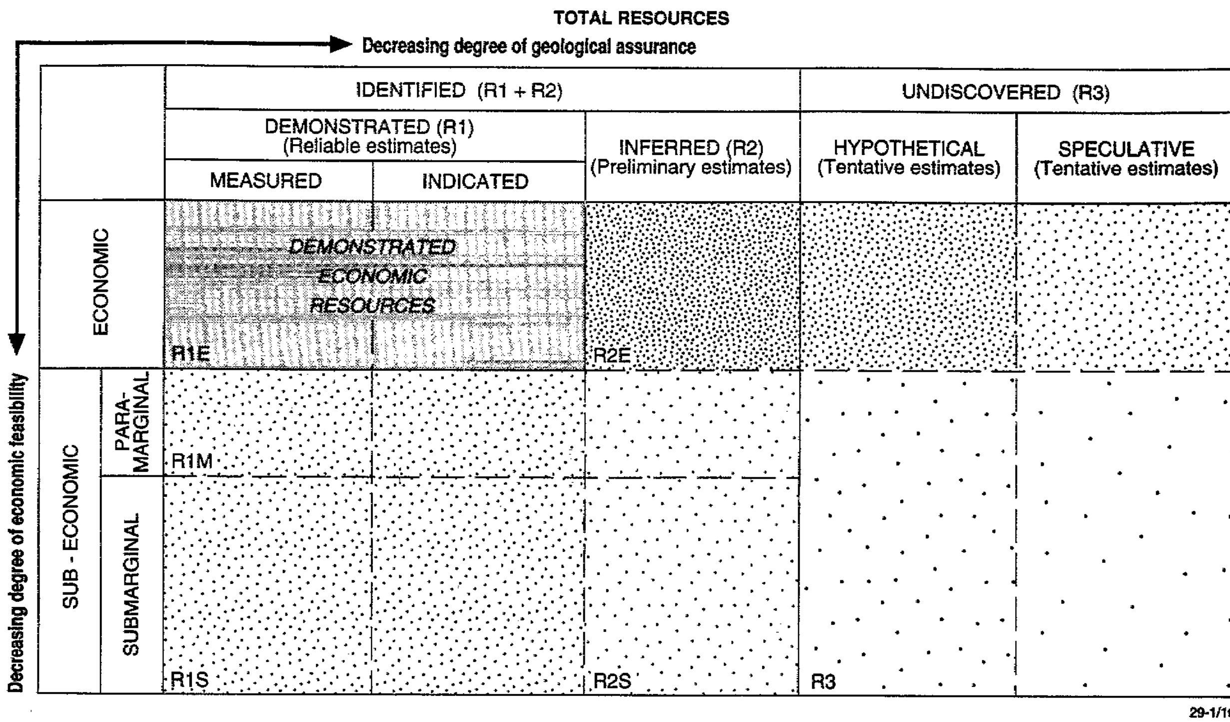
1. Identified resources

82. Most existing national and international assessment programmes are limited to the assessment of identified resources, especially demonstrated economic resources (DER), i.e., that part of total resources that has been identified by exploration and drilling and can be extracted economically under current conditions (see figure 2).

83. The stock of DER can be related to the changing demand for (and therefore production of) a particular commodity by the resource-production (R/P) ratio. Time series of production, DER and R/P ratio illustrate the availability of mineral resources through time, and indicate the effects of past changes in demand, including their major social and economic impacts. They also demonstrate that the stock of DER is not a fixed stock that is continually being depleted. On the contrary, it is continually being renewed either by discovery of new economic resources or by transfer from the large pool of known but previously sub-economic resources, as a result of technological advances or price rises induced by scarcity.

84. In general, the annual production of mineral commodities has increased greatly and steadily this century, but DER have also increased, so that R/P ratios have been maintained. In the case of bauxite, however, DER has been maintained but the R/P ratio has declined because of greatly increased annual production.

Figure 2. Australian resource classification system a/



Key

R - in situ resources

R1 - known deposits (reliable estimates)

R1E - economically exploitable

R1M - marginally economic

R1S - sub-economic

R2 - extensions of known and newly discovered deposits (preliminary estimates)

R2E - economically exploitable

R2S - sub-economic

R3 - undiscovered deposits (tentative estimates)

Source: Australian Bureau of Mineral Resources (1984); see "BMR refines its mineral resources classification system", Australian Mineral Industries Quarterly, vol. 36, No. 3 (1984).

Note: Sub-economic categories also represent unusual concentrations of the relevant elements, and can be reasonably well defined for particular deposit types.

a/ Modified McKelvey system, also showing United Nations resource categories.

85. The large tonnage commodities, such as coal, iron ore, bauxite and phosphate, have large R/P ratios (in the hundreds of years). However, such minerals occur in near-surface deposits: the capacity to continue to renew the stock of their DER is in some doubt. Moreover, such mining also has the largest immediate (if transitory) environmental impact.

86. For most of the metallic minerals, R/P ratios are much smaller (in the tens of years), but again it has been possible to maintain their ratios, reflecting the capacity of the minerals industry to take a relatively long-term view of future demand and of the factors likely to affect it, and to make appropriate investment in exploration and development. The time-lag between such investment and the establishment of new DER is typically 10 years or more. 35/

87. Resource/production ratios therefore provide a clear horizon of the sustainability of supply, usually of about 30 or 40 years. In terms of the supply constraint, this also provides a horizon of sustainability for production and consumption patterns.

2. Undiscovered resources

88. In contrast to the situation for petroleum, there are no reliable global estimates for the undiscovered resources of metallic minerals. There are many different types of deposit, the processes that generate them are very complex and less well-known than those that generate petroleum deposits, and methodologies for estimating undiscovered resources are much less reliable. Most of the methods that have been employed are of a very general character, and do not permit information about undiscovered resources to be linked in integrated systems of land use and management.

89. This is unfortunate, since it tends to foster the notion that metallic mineral resources are unlimited, since the total amount of most metals and other mineral commodities in the earth's crust is very high. In most rocks, however, metallic elements occur in very low concentrations and not in discrete minerals, so that their extraction is not feasible. Metallic mineral deposits, whether currently economic or sub-economic, result from particular conjunctions of processes in the earth's crust that have led to the deposition of unusual concentrations of metals as mineral ores in particular locations.

90. It is possible that mineral deposits of the kinds currently regarded as economic or sub-economic will be quite limited by comparison with the resources already identified. Their distribution is highly heterogeneous at various scales, both in area and in depth. Different kinds of deposit are characteristic of different geological environments, so that their occurrence is limited to particular mineral provinces. Moreover, many deposit types are formed close to the earth's surface, so that the opportunities for discoveries below the uppermost few kilometres are likely to be relatively limited.

91. Many of the more prospective terrains of the world have already been extensively explored by modern methods, so that the more readily detected deposits have already been discovered. Exploration techniques, however, are continually being improved in the search for concealed deposits. Other terrains

have only recently been opened to the international exploration industry, and there will undoubtedly be major discoveries over the next few decades. It is likely, therefore, that the horizon of sustainability can be pushed back into the second half of the twenty-first century. Nevertheless, based on the current state of knowledge, it is prudent to recognize that there may be real problems in meeting demand over the next century, which may be increased by political factors and more generally by restrictions on the availability of land for exploration, as discussed below.

C. Strategic factors

92. The uneven distribution of mineral deposits world wide means that the sources of supply of some commodities, such as platinum, chromium, vanadium and manganese, are highly restricted geographically. In recent decades, for example, South Africa and the former USSR have accounted for over 80 per cent of world mine production of platinum group metals. Such commodities will continue to attract high exploration interest in order to widen the supply base.

93. The dependency on supplies of minerals from outside sources has led some countries to the identification of strategic minerals, an imprecise term that embraces the concepts of criticality and vulnerability. At the national level, the criticality of a mineral depends on its contribution to the national economy and general physical well-being, and critical minerals may in some cases be vulnerable to interruptions of supply. In 1985, a report by the Office of Technology Assessment of the Congress of the United States of America noted that only three nations (South Africa, Zaire and the former USSR) account for over half of the world's production of chromium, cobalt, manganese and platinum group metals, which are essential in the production of high temperature alloys, steel and stainless steel, industrial and automotive catalysts, electronics and other applications that are critical to the United States economy and the national defence. 36/

94. A fuller knowledge of potential sources of supply is therefore likely to be of increasing interest to many countries.

95. A number of countries have participated in producing an International Strategic Minerals Inventory (recently renamed International Studies of Minerals Issues), which has produced valuable information on the identified resources of many commodities, mainly metals but also important non-metallic industrial minerals, such as phosphate and graphite. However, it has not proved possible to make estimates of undiscovered resources (see figure 2).

D. Availability of land for exploration

96. Population pressures world wide, and attendant environmental impacts are causing increasingly severe competition for land use, and there has also been a reaction against mining in some countries. The need to meet the global demand for mineral resources from the most efficient sources world wide is not readily appreciated either by local communities, whose lifestyle may be affected by major mining projects, or by national conservation movements. This is

especially the case if the demand is perceived to be the result of extravagant or wasteful consumption patterns with undesirable environmental impacts. It is therefore important that strategies to maintain supply be linked to effective strategies for moving to sustainable production and consumption patterns.

97. Such factors, related to population pressure and environmental impacts, can militate against the vigorous exploration programmes that will need to be pursued in the most prospective areas world wide if essential mineral supply is to be maintained. It must be recognized that only a relatively small proportion of continental terrains are highly prospective for each of the various metallic mineral deposit types. Such terrains need to be identified, and their mineral potential taken into account in determining needs for mineral exploration, both in a global context and within the context of an integrated approach to land-use planning. This will not be feasible unless a comprehensive information base is developed on mineral resource potential, that can be integrated with other land-use information.

E. Assessment of mineral resource potential

98. Terrains that are prospective for particular mineral deposit types have been called permissive tracts and their identification is the first step in the assessment of mineral potential and of unidentified resources. Such permissive tracts can be identified on the basis of geoscientific mapping programmes carried out by national geological surveys. In conjunction with information on mineral occurrences, such mapping permits qualitative estimates of prospectivity and resource potential. It provides the basis for assessment and investment in exploration by mining companies. Mineral maps and/or metallogenic maps can be produced as by-products of geological surveys. 37/

99. It is also desirable to assess not only the most likely geographic sources but also the quantities of undiscovered deposits in both the hypothetical and speculative categories. Hypothetical resources are those "that may reasonably be expected to exist in a known mining district or mineral province under known geological conditions, while speculative resources are those that may occur either in known types of deposits in a favourable geological setting where no discoveries have previously been made, or in yet unknown types of deposits that remain to be recognized". 38/ Both hypothetical and speculative sources contain deposits that are likely to be economic or marginally economic under current criteria.

100. Several approaches have been made to the quantitative assessment of undiscovered mineral resources. 39/ Most notably, a three-part method of quantitative assessment has been applied by the United States Geological Survey since 1975. Its original purpose was to provide quantitative resource information in a form consistent with an economic analysis so that mineral resource values could be compared with other competing uses of land. 40/ Such assessments are most reliable for relatively small geological provinces in which the mineral deposit geology is already well known.

101. More recently, there has been a proposal to make a national three-part assessment, to provide a consistent, usable minimum level of current

mineral-resource information, together with estimates of total undiscovered mineral endowment, for the entire United States. 41/ It was suggested that such an assessment is essential for ensuring that all domestic mineral resources will be considered in planning the optimum use of the State's public lands and for securing long-term mineral supplies from national and international sources.

102. As a first step in this programme, it was also proposed to carry out a two-year preliminary quantitative national assessment based on existing national data to produce maps showing the outlines of tracts that are permissive for the types of deposits concerned. Such a preliminary assessment would be of great value for planners in the United States, and similar assessments would be of even greater value in developing countries with substantial resource potential. Moreover, the value of all such national assessments would be greatly enhanced if they could be examined in the context of global potential and global resource needs.

103. However, it is unrealistic at present to propose a similar quantitative assessment world wide. In most countries, the level of geological knowledge is inadequate for assessments by this three-part methodology, and there are impediments to the acquisition of such knowledge, both in terms of expertise and financial resources. 42/

104. A more realistic global goal would be to produce maps delineating permissive tracts world wide, using internationally agreed criteria, which would involve only the first steps in the proposed United States preliminary assessment, namely:

(a) Compile existing data;

(b) Apply limited mineral-deposit models;

(c) Construct maps of delineated permissive tracts.

105. Such maps would provide the basis for iterative assessments of undiscovered resources as data became available. Although the assessments of individual tracts would generally be, at best, semi-quantitative, the global picture thus provided would allow much more realistic assessments of sustainability beyond the horizon currently provided by identified resources.

106. Of more immediate importance, such maps would assist the consideration of minerals issues within an integrated approach to land-use planning. They would allow the needs for mineral exploration and development to be assessed in relation to other land-use needs. Moreover, since perceived mineral resource potential has been identified as the most important single criterion for the international mining industry in assessing the investment environment for exploration, a global programme identifying permissive tracts world wide would be of great value in assisting the effective, efficient and socially harmonious operation of the industry.

107. For example, such a programme would assist local and national populations in appreciating the wider global interest in keeping the principal permissive tracts of the world open for exploration and development as far as possible, so

that the global endowment of mineral resources can be effectively managed and utilized.

108. It is important to distinguish between the scope of mineral exploration and the scope of mineral developments. It must be recognized that, although it is necessary to explore over large areas, this can largely be accomplished by non-intrusive techniques, such as aeromagnetic surveys, and exploration is not generally incompatible with other land uses. Mineral development per se, following successful exploration, will continue to affect only relatively small areas. If current best practice in integrating environmental and development concerns is implemented, 43/ the short-term environmental impacts of mining can be minimized within acceptable limits, and its long-term impacts can be made negligible. It also needs to be emphasized that, under appropriate environmental guidelines, the needs for exploration and development are not incompatible with other forms of land-use, including agriculture and national parks.

109. Accordingly, at its second session, the Committee on Natural Resources concluded that the United Nations could make a major contribution to the long-term management and sustainable development of mineral resources through developing a global knowledge base, at appropriate scales, of the potential for mineral resource exploration and development. 44/

Recommendation 3

110. In accordance with recommendations 1 and 2 (see paras. 66 and 73 above), it is recommended that a global knowledge base on mineral resource potential, especially the identification of permissive tracts be developed and integrated with other land information, so that the horizon of sustainability can be extended and land-use planning can properly take into account national and global needs for mineral exploration and development.

111. The Committee is aware that much of the information required is already being collected in many countries, and that a number of existing international organizations (both governmental and non-governmental) could assist in the development of such a global knowledge base. The World Bank has also recognized the importance of such information for developing countries. It is believed, therefore, that a global knowledge base could be developed at relatively low cost by building on existing efforts of many institutions at the national and regional levels. The United Nations needs to define the global mission and provide the necessary coordinating mechanisms. An advisory body is needed to set standards for organizations to follow in collecting and collating geoscientific information, including the development of globally consistent approaches to the definition of permissive tracts and the assessment of resource potential.

112. Countries with well-established geological surveys and mineral industries, as well as and those with existing international minerals programmes, can play leading roles in the development of such a programme at the regional level. The newly created agencies for mineral resources in the Central European countries could also play an immediate role. There will be a need to provide financial and technical assistance to some developing countries to carry out data

acquisition and interpretation; other countries, such as the countries of the former USSR, need substantial assistance to ensure that information gathered in the past on a confidential basis is not irrevocably lost and contributes to the global knowledge base.

113. Such a global knowledge base is clearly essential if the concept of sustainable consumption patterns is to be developed to take into account resource availability as well as environmental impacts. This is in accord with the objective established in chapter 40 of Agenda 21 to strengthen local, provincial, national and international capacity to collect and use information in decision-making processes (para. 40.5 (b)). Chapter 40 also recognizes the need to carry out inventories of environmental, resource and developmental data, and it suggests that data-collection activities need to be strengthened within the organs and organizations of the United Nations system, including, in the area of land resources (para. 40.8).

IV. CONCLUSION: REVIEW OF RECOMMENDATIONS

114. The actions proposed in recommendations 1, 2 and 3 (paras. 66, 73 and 110 above) are relatively non-controversial and low cost. Much of the information required is already being collected at national level. It is appropriate for the United Nations to assist in the management of global issues by coordinating the collection of information to provide a global framework for policy formulation at both the international and national levels.

115. The commission on mining and materials proposed under recommendation 1 (para. 66 above) could perhaps be appropriately placed in the Department for Development Support and Management Services, where it would provide direct support to the Committee in its advice to the Economic and Social Council, or alternatively in UNCTAD, where it could provide technical underpinning for UNCTAD's current brief.

116. The capacity to coordinate the activities identified in recommendations 2 and 3 (paras. 73 and 110 above) appears to lie principally in the Department for Development Support and Management Services, the principal operational arm of the United Nations Secretariat, and with the regional commissions. More specifically, the Division for Environment Management and Social Development provides a multidisciplinary approach in areas of natural resources, and provides support services to CNR; its Natural Resources, and Environment Planning and Management Branch has particular expertise in the minerals sector.

117. The Department has not hitherto engaged in such specific activities as those recommended above. However, in the course of its technical assistance activities the Department has participated in the creation of a number of national mineral inventories and geo-databases. The information and expertise developed during the execution of such projects could readily be applied to a coherent mineral-resource assessment programme, coordinated by the United Nations and designed to unite and standardize current independent and regional initiatives.

Notes

1/ Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, vol. I, Resolutions Adopted by the Conference (United Nations publication, Sales No. E.93.I.8 and corrigenda), resolution 1, annex II.

2/ See, for example, Preston Cloud, "Entropy, materials and posterity", Geologische Rundschau, vol. 66, No. 3 (1977).

3/ Our Common Future (World Commission on Environment and Development, 1987).

4/ See, for example, "Indicators of sustainable development for decision-making", report of a workshop held in Ghent, Belgium, 9 to 11 January 1995 (Belgium: Federal Planning Office).

5/ Mineral deposits are renewable on geological time-scales, and indeed some kinds of mineral deposits, such as those in major oceanic rift systems, are being formed at the present day. However, terrestrial deposits of the kinds and grades currently being mined are essentially non-renewable.

6/ See Crispin Tickell, "What we must do to save the planet", New Scientist (7 September 1991).

7/ See the Rio Follow-up at Regional Level: A Review of Major Regional Policy Implications of the Outcome of the United Nations Conference on Environment and Development (United Nations, Geneva, 1993).

8/ Report of the United Nations Conference on Environment and Development ..., annex I.

9/ The custom of including fossil fuels within a general definition of mineral resources is illustrated, for example, in International Mineral Development Source Book, J. F. McDivitt, ed. (Golden, Colorado: Forum for International Mineral Development, 1993). However, issues relating to fossil fuels are not within the formal mandate of the Committee on Natural Resources but within that of the Committee on New and Renewable Sources of Energy and on Energy for Development. Consequently, no recommendations are made in the present paper concerning fuel minerals. Nevertheless, some reference to fuel minerals is included because the broader issues of exploration and development in the mining sector encompass the fuel minerals, and because the issues of availability and environmental impacts of both metallic and industrial minerals are closely linked to energy use.

10/ Such as those of the Scientific Committee on Problems of the Environment of the International Council of Scientific Unions, notably in the fields of biogeochemical cycles, and health and ecotoxicology.

11/ See "Development, environment and mining: enhancing the contribution of the mineral industry to sustainable development", post-conference summary of the International Conference on Development, Environment and Mining, Washington, D.C., 1-3 June 1994.

12/ See, for example, L. Arizpe, R. Costanza and W. Lutz, "Population and natural resource use", in An Agenda of Science for Environment and Development into the Twenty-first Century, J. C. I. Dooge et al., eds. (Cambridge University Press, 1992).

13/ See H. E. Daly and J. B. Cobb, Jr., For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future (Boston: Beacon Press, 1989); see also Agenda 21, chap. 4, paras. 4.10 and 4.11, which call for consideration of new concepts of economic growth less dependent on the Earth's finite resources.

14/ See, for example, data for the United States of America and Japan in F-W. Wellmer and M. Kürsten, "International perspective on mineral resources", Episodes (September 1992); fig. 12.

15/ See Wellmer and Kürsten, op. cit., fig. 10, showing a trend of gradually increasing consumption of base metals in industrialized countries between 1970 and 1990.

16/ See Wellmer and Kürsten, op. cit., fig. 9.

17/ See, for example, J. F. Bookout, "Two centuries of fossil fuel energy", Science, No. 253 (1989).

18/ See H. E. Daly, Steady State Economics (San Francisco: W. H. Freeman, 1977); see also P. Demeny, "Demography and the limits of growth", Population and Development Review, supplement No. 14 (1988).

19/ See B. J. Skinner, "Resources in the twenty-first century: can supplies meet needs?", paper presented at the World Natural Resources Colloquium, Twenty-eighth International Geological Congress, Washington, D.C., 1989.

20/ Estimate in Wellmer, personal communication (1994).

21/ See H. Schütz and S. Bringezu, "Major material flows in Germany", Fresenius Environmental Bulletin, vol. 2, No. 8 (1993); note also that water inputs amount to 730 tons per capita (mostly cooling water for power plants).

22/ See P. Gilding and G. Mawer, "Eco-competitiveness", in Management (April 1996); in addition, Agenda 21, para. 4.18, notes that reducing the amount of energy and materials used per unit in the production of goods and services can contribute both to the alleviation of environmental stress and to greater economic and industrial productivity and competitiveness.

23/ See Mineral Commodity Summaries 1995 (United States Department of the Interior: Bureau of Mines).

24/ See, for example, A. Kelly, "The future of metals", Minerals Industry International, No. 996 (1990).

25/ Reported in F. W. Wellmer, personal communication (1994).

26/ F. Hinterberger, S. Kranendonk, M. J. Welfens and F. Schmidt-Bleek, "Increasing resource productivity through eco-efficient services", Wuppertal Papers, No. 13 (May 1994).

27/ See, for example, W. G. B. Phillips, "Factors affecting the long-term availability of bulk minerals for the construction industry", in Resources and World Development (John Wiley and Sons, 1987).

28/ See "Mineral resources and sustainable development: a workshop", Technical Report, No. WF/94/12 (Keyworth, Nottingham: British Geological Survey, 1994).

29/ See P. J. Cook, "Societal trends and their impact on the coastal zone and adjacent seas", in Proceedings of the International Conference "Coastal Change 95" (Bordeaux: Bordomer/Intergovernmental Oceanographic Commission, 1995).

30/ See "International strategic minerals inventory summary report, 1984: phosphate", United States Geological Survey Circular, No. 930-C.

31/ See, for example, R. P. Sheldon, "Industrial minerals, with emphasis on phosphate rock", in Resources and World Development, op. cit.; Phosphate Deposits of the World, A. J. G. Northolt, R. P. Sheldon and D. F. Davidson, eds., vol. 2, Phosphate Rock Resources (Cambridge University Press, 1989); and Mineral Commodity Summaries 1995 (United States Department of the Interior: Bureau of Mines).

32/ The Commission noted, for example, the inputs provided from various sources, including an expert seminar on the theme "Sustainable consumption and production patterns" (Cambridge, Massachusetts, 18-20 December 1994); sponsored by the Massachusetts Institute of Technology and OECD.

33/ A. G. Darnley and others, "A global geochemical database for environmental and resource management: recommendations for international geochemical mapping", final report of IGCP Project 259, "Earth sciences 19" (UNESCO, 1995).

34/ See, for example, F-W. Wellmer and M. Kürsten, op. cit.

35/ See "Lead-time study: review of progress, 1993", International Strategic Minerals Inventory, Thirteenth Working Group Meeting (published by the United States Geological Survey; prepared as a cooperative effort among earth-science and mineral resource agencies of Australia, Germany, South Africa, the United Kingdom and the United States of America).

36/ See United States Congress, "Strategic materials: technologies to reduce United States import vulnerability" (Office of Technology Assessment, Washington, D.C., 1985).

37/ See A. Emberger, "Geological mapping and mineral maps", in International Mineral Development Source Book, J. F. McDivitt, ed. (Forum for International Mineral Development of the Colorado School of Mines, 1993).

38/ See "BMR refines its mineral resources classification system", Australian Mineral Industries Quarterly, vol. 36, No. 3 (1984).

39/ See, for example, J. P. Dorian and J. Zwartendyk, "Resource assessment methodologies and applications", Materials in Society, vol. 8, No. 4 (1984).

40/ See D. A. Singer, "Basic concepts in three-part quantitative assessments of undiscovered mineral resources", Non-Renewable Resources, vol. 2, No. 1 (1993).

41/ J. A. Briskey, Jr., "A proposed national mineral resource assessment", Non-Renewable Resources, vol. 1, No. 4 (1992).

42/ See Deverle P. Harris and others, "Evaluation of the United States Geological Survey's three-step assessment methodology", research report to the United States Geological Survey (1993).

43/ See, for example, the Berlin Guidelines adopted by the International Round-table on Mining and the Environment (Berlin, June 1991) (E/C.7/1993/10, annex I).

44/ See Official Records of the Economic and Social Council, 1994, Supplement No. 6 (E/1994/26).
