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UNITED NATIONS
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DISCUSSION MEETING ON ADVANCED MATERIALS FOR DEVELOPING COUNTRIES VIENNA, 7-10 DECEMBER 1987

Report*

Prepared by

the UNIDO Secretariat

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I. INTRODUCTION

A group of materials scientists and specialists met in Vienna from 7 to 10 December 1987 to exchange views and advise UNIDO ona possible programme of action to assist in the introduction of new materials and materials-related advanced technologies in developing country's economies. The participants at the meeting and the documents prepared for it are listed under annex 1 and annex 2 respectively.

Mr. Klaus M. Zwilsky was elected Chairman of the meeting with Mr. Pradeep Rohatgi as Rapporteur.

The objectives of the meeting were:

- To consider the developments taking place in the field of new materials and the related technolgies, in particular the experiences of some developing countries;

- To discuss the role of materials vis-a-vis the developing countries;

- To discuss the necessary infrastructure for wide scale introduction of new materials to developing countries.

- To make a recommendation on the subject as regards the measures to be taken at the national and international levels.

The meeting was one of a series initiated by the UNIDO Secretariat in connection with its new programme approach for its work in the development and transfer of technology. The meeting was intended as a preparatory activity inthe preparation of a progress report on the implementation of IDB.3/26* to the Programme and Budget Committee.

In his address, Mr. F. S. Souto, Deputy Director-General, referred to the necessity of introducing new materials and related advanced technologies into developing countries. Mr. K. Venkataraman, Senior Technical Adviser, described UNIDO's work in the field of materials and briefed the experts as to the goals of the meeting.

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* Title of IDB 3/26

II. RECOMMENDATIONS

National action

The meeting recommended that developing countries include a policy analysis for materials in their planning efforts. Specifically such an analysis should include any abundant local resources - both renewable and nonrenewable - that may be unique to the country and in the development of which materials science and technology could play a major role. The evaluation of anatase as a new ore for titanium production in Brazil, laterite and clay-based products for improved performance of bricks in India, and several developing countries, and the use of coconut leaves and fibres for roof thatching and ropesin Asian countries are good examples of the development of local resources through materials-based advanced science and technology.

The meeting recommended that developing countries include the build-up of a materials science and technology infrastructure as high priority in their planning. Such an infrastructure could provide the foundation for any development based on natural resources or for a value-added as well as a manufacturing capability.

The basic building blocks for building infrastructure are government, universities and industry working in concent to achieve specific goals. Government has to provide the leadership, policy analyses, and often funding to institutes and universities for support of materials science and engineering, including design, testing, quality control and standardization. The contribution of the universities is the education of scientists and engineers as well as fundamental research. Contacts between scientists in the developing countries with others working in the field is also an important component of university activities. The contribution of industry is to develop materials or manufactured products for internal consumption and exports. Government must also provide clear materials related guidelines to industry on patent policy, taxation and import/export regulations as well as a rationalised use of materials related to energy intensity and recyclability.

It can not be over emphasized that a critical mass of materials scientists and engineers is necessary for a country to continuously improve its products and introduce new ones for its own economy and for export.

The meeting recommended that, as part of the effort to build infrastructure, developing countries encourage the formation of local professional societies in materials science and engineering and/or encourage their scientists and engineers to join technical societies such as ASM INTERNATIONAL and others.

Such societies provide a meeting ground for government, university and industry technical personnel to meet and exchange ideas informally. They also provide a great deal of technical information to their members that includes course material, handbooks, abstracting services and materials-selection software at reasonable cost.

The meeting recommended that the developing countries concentrate on human resource development, also a very necessary ingredient for infrastructure building. Scientist talent will be fostered through government support of universities, as already discussed; however, special education and training are necessary for plant operation, materials processing and manufacturing engineers and technicians. Continuing education courses, specialized seminars, courses taught through professional societies can all be of benefit but need to be encouraged to succeed.

International co-operation

Bilateral or multilateral interaction between countries is a mechanism frequently used when transferring technology. The elements on which co-operation is desirable are listed here under, with some examples. It is important to point out that the impetus for such action can come from a developing or developed country, as well as from an international organization such as UNIDO or a professional society, laboratory or institute.

The meeting recommended that workshops and exchanges be increased by and with any developing country interested in increasing its materials science and technology base. One model is the UNIDO -Czechoslovakia Joint-Programme for

International Co-operation in the Field of Ceramics that provides for technical workshops and short-term study tours. Another model is the lecture programmeof ASM INTERNATIONAL that defrays expenses incurred by visitors to India who increase their stay in that country for a series of lectures when invited to do so. Likewise the OKTEN (transfer of know-how through expatriaot nationals) provides for experts working in advanced countries to return to their countries of origin for short visits to render technical advice.

The meeting recommended that opportunities for the training of scientific and technical personnel be increased in the developing countries. For the short term training of scientists, the International Centre for Theoretical Physics in Trieste is a good model. Potential interaction with laboratories in developed countries is another desirable mechanism that could perhaps be funded by existing mechanism, incorporatingco-operation with developing countries in existing programmes between developed countries. An additional mechanism is the teaching of courses in developing countries by members of professional societies who could use course work available through professional societies such as ASM INTERNATIONAL.

The meeting recommended that additional effort be placed on data base generation and increasing the availability of existing data bases to developing countries. Although UNIDO is identified as a facilitator for such activities, both developing and developed countries need, in addition, to interact more directly to identify available data bases in developed countries of direct benefit to a specific technical area in a developing country.

The role of UNIDO

The meeting recommended that UNIDO promote the establishment of an International Materials Assessment and Application Centre (IMAAC) for in an depth analysis and promotion of the rational use of materials. There is at present no institution at the international level which addresses the issues relating to the development and use of diverse materials including new and advanced materials in a trans-sectorial and integrated fashion. Such an institution would provide a forum and fuction as a protagonist for international co-operation based on an integrated approach to the development and use of materials, while also facilitating the promotion of activities relating to the application of modern science and technology to the development of materials based on local resources and capabilities in developing countries.

The desirable characteristics for IMAAC are described below:

(a) The Centre should have, as a minimum, the functions of collecting, analysing and disseminating information relating to the diverse materials and undertake or promote techno-economic studies, especially those related to unique resources not likely to be studied by others. It should also organize and provide advisory services and facilitate training and research development;

(b) The Centre should have a network of participating institutions in various countries including specialized centres of excellence;

(c) The Centre should have a relatively limited number of staff constituting an interdisciplinary group;

(d) The training and R+D facilities of the host institution as well as the network of distributed participating institutions should provide a basis for promoting training and R+D activities.

(e) The Centre should have, as one of its important purposes, the promotion of R+D into materials-related problems of developing countries;

(f) The Centre should promote a problem-oriented network of laboratories interested in working within a specific technical area and who agree to undertake a joint programme, share the results and supplement their activities with information exchanges and reciprocal visits. Laboratories of both the developing and developed countries could be involved in such efforts;

(g) The Centre should be inter-institutional (rather than intergovernmental) in character, but it should be understood that the participating institutions should be in a position to contribute resources to the Centre's activities, for example by seconding its professional staff to work for the Centre;

(h) The Centre should be backed by the commitment of the host country willing to provide the facilities necessary for its operation; and

(i) Its establishment would be considerably facilitated if an existing institution of excellence were able to offer its infrastructure to locate the Centre.

The UNIDO Secretariat is requested to further promote the concept with interested countries with a view to the early establishment of IMAAC.

The meeting recommended that UNIDO's (Industrial Technological Information Bank (INTIB) develop specialized data bases for specific new materials and technologies not covered by the existing data bases. This is especially important for materials unique to a particular region where little data may come from developed countries.

The meeting recommended that UNIDO enhance its technological publications to include greater compilation and dissemination of information in the field of new materials. Especially important would be the preparation by INTIB within its Guides to Information Sources one for specific materials, as well as a directory of research and development institutions in developing countries particularly working in the field of materials. UNIDO should prepare a roster of emminent experts in the field of new materials and continue the publication of its Monitor on Advanced Materials, increasing its dissemination.

UNIDO Secretariat was recommended to investigate the possibility of building up a network of R+D institutions in the field of new materials which would co-operate in research and training programmes and exchange technical information.

The meeting recommended that UNIDO implement its programme on new materials, as indicated in document IDB. 3/26, namely:

(a) Information analysis and the monitoring of technology trends in selected materials and the development of an information network for new materials;

(b) Support national policy and programmes in the field of materials, including helping the establishment of material testing laboratories in developing countries; and

(c) Develop programmes for international co-operation, including promoting the establishment of networks of centres of excellence in selected materials. An expert group meeting on new materials technologies is foreseen for 1988, subject to the availability of extra budgetary resources.

The meeting recommended that UNIDO increase its interaction with professional societies in the field of materials. In this connection it was noted that the ASM INTERNATIONAL will be holding the first World Materials Congress in September 1988 and the Organization of American States is holding a conference on materials particularly adapted to developing countries in October 1988. It is recommended that the UNIDO Secretariat participate as this would be a unique opportunity to present a coherent view of the needs of the developing world in the materials area to a worldwide audience. The meeting recommended that UNIDO promote an expert group discussion to provite input to these meetings.

III. Analysis and Experience

III.1 Impact of materials on industry and the economy

Broadly defined, the term "material" denotes physical matter used to make things, machines, structures and other objects required by man for everyday life. Covering a wide spectrum of types and uses; materials and materials technolgy thus play a key role in the industrial, economic and social development of all countries. These are:

Metals and their alloys
Inorganic materials, including ceramics
Organic materials, including polymers
Composite materials
Renewable materials
Energy-related materials
Electronic components
Materials processing and manufacturing
Conservation, recycling and substitution.

What distinguishes materials technologies from the other technologies and sciences that are the subject of current attention is that materials are not an end product in themselves - they are needed to permit engineering and other structures to fulfill their functions. In this sense then, materials have an underpinning role, an essentially enabling technology, providing a framework for all industrial sectors.

Developments in materials technology over the last two decades have led to new metal alloys, fine ceramics products, engineering polymers and hybrid material composites, all of which are replacing the more traditional metal products at a remarkable rate. Changes in materials thus change industry and the pattern of industrial development.

New materials can be viewed as substances or combinations of substances, which are developed by applying basic principles to their preparation and production, with a view to their utilization in new or old applications.

The development of new materials focuses primarily on the creation of properties needed in advanced engineering applications and their substitution for existing rare or critical ores and metals in short supply and/or vital to a nation's economy.

Materials for advanced engineering applications, which is the goal of R+D facilities throughout the world are often the key to progress in high technology fields, such as aeronautics, informatics, microelectronics and traditional manufacturing as for instance automobiles and consumer goods.

Governments of industrialized countries are particularly interested in reducing their dependence on traditional sources of supply of vulnerable or critical ores and/or metals.

If in a certain area the adoption or creation of "appropriate technologies" or "advanced technologies" is considered, it is imperative that the total materials cycle also be considered.

Ores, hydrocarbons, wood, oxygen and other substances are taken from the earth, sea and the atmosphere in crude form. They are extracted, refined, purified and converted into simple metals, chemicals and other basic raw materials. Advanced technology is applied to modify these industrial raw materials to make intermediates such as alloys, ceramics, electronic materials, polymers, composites and other compositions, i.e. advanced materials that meet performance requirements. Manufacturers of finished products shape these advanced materials into parts for assembly. The cycle is completed when the product's useful life is over, and it either returns to the earth, the sea or the atmosphere as waste or is dismantled for recovery of basic materials that re-enter the cycle.

The activities of materials industries have to be seen with respect to the entire materials cycle. Given the many different parts of this cycle, it is evident that only a multidisciplinary approach can respond to all the technological and market questions involved. From raw material to finished product and its discard or recycling, five questions are paramount:

- Energy intensity of processes and products
- Environmental impacts
- Impact or employment and other social structures
- Role of innovation and technological leadership
- National materials policy.

The total materials cycle is not only an essential framework for establishing new materials industries, it is also a means for assessing the influence of changes in materials technologies introduced by advancing techniques in other disciplins. The, for example, adoption of "new technologies" can severely disturb the materials cycle of traditional industries.

The key role of materials technologies in future industrial development is illustrated by the major materials developments listed in the 1979 US National Academy of Sciences five-year outlook, as being those likely to have a major impact on society from the present to the turn of the century:

Synthetic polymers
High-performance resin and metal-matrix composites
Silicon nitride and silicon carbide ceramics
Rapidly-solidified superalloys
Single-crystal engine components (e.g. turbine blades)
Fibre-optic transmission
Very large-scale, integrated-circuit silicon chips
Bubble memories for computers
Semiconductor infrared detectors
Powder metallurgy consolidation techniques
Precision casting
Laser treatment of surfaces
Computer-aided design and manufacturing

The driving forces behind the materials developments are various technological, social and environmental requirements:

Improved performance, integrity and reliability of higher durability of engineered systems products.
High efficiency, low-energy mechanical power;
Light weight, high-strength structures;
High-speed information technologies; and
Increased productivity of manufacturing technologies.

To fulfill these requirements, there is a continuous demand for materials with specific functions - mechanical, thermal, optical, electro-magnetic, chemical, biological and electronic.

III.2 Materials technologies and development

The materials picture in the developing countries and in the poorer sections of advanced countries, is one of very low availability of materials per capita and poor quality. In the development context, materials filling basic human needs such as food, housing, clothing, energy, and water are more important than materials for advanced weapon systems, faster aeroplanes and high-tech applications. While some knowledge-driven advances (e.g. rapidly solidified materials, plasma and vapour-deposited materials, surface-processed and interface-tailored metals, ceramics and composites and nano-structured materials) will indirectly contribute to development, they need to be selectively steered to accelerate the availability of materials for development. Development-oriented materials technology leading to greater availability and better qualities of materials per capita will require smaller, lighter, stronger, longer-lasting recyclable materials made from local renewable and abundant resources. They will be made using high-information, simple processes with low energy (preferably in the form of solar and biomass) and low capital requirements, but high labour content. Materials based on plant-based products and abundant resources like clays, stones, rocks, aluminium, silicon and oxygen should receive increasing attention along with biological processes to process and preserve materials. Materials for solar energy and fusion energy should receive high priority along with materials for food production and storage, cloth and paper, materials for water purification and health care.

Developing countries may develop their own new materials and uses, e.g. composites, suitable to their resources and conditions. However, the diversity of conditions in developing countries and the endowment of raw materials will require different approaches to be evolved by each country. The question of which material technology is most appropriate cannot be answered through comprehensive catalogues or criteria in a general manner. Each case has to be considered individually to plan basic materials industries; however, the following must be considered:

Location of natural resources

Possible extraction methods

Location and method of processing

Impact on the natural environment

Energy implications

Cost of extraction and processing

Commercial value at current and likely future prices

Export possibilities

Impact on imports

Social-economic effects

III.3 Position of some of the countries and basic targets for materials technology

The per capita GDP data for different countries (Table 1) shows a linear log-log relationship with their per capita consumption of different materials including steel, copper, aluminium, cement, zinc and tin. This means that the process of development (insofar as it is reflected in rapidly increasing per capita GDP) will inevitably require increases of ten to a hundred times the quantities of materials produced today (Table 2). Most of the developing countries are at a stage where unit inputs of materials and energy to produce an additional unit of GDP are likely to continue to increase for several years. Possible reductions in requirements of materials per capita due to miniaturization and substitution by lighter weight, high-strength materials and parts consolidation, are more than likely be offset by increasing requirements of materials due to rapidly increasing populations and increasing materialism and consumerism.

The challenge for materials technology for development, for at least the next fifty years, will be to increase the availability of materials for housing, water, food, energy and health care, by as much as ten to hundred fold. This must be achieved, moreover, without pressures on resources, energy requirements, environment and employment. The paradigm for materials technology for development should lead to development and production of basic need-based materials (Table 3) which are smaller, lighter, longer lasting, low cost, low energy and recyclable. These should be based on abundant and renewable resources which can be locally processed, using simple employment-generating and non-polluting technologies.

The potential opportunities and problems advanced materials present for developing countries has been identified by the United Nations Centre for Science and Technology for Development in co-operation with BAM (the Federal German Institute for Materials Research and Testing) as follows: ATAS Bulletin on "Advanced Materials and Development" to be published in early 1988.

Table 1. Per capita consumption of metals in selected countries

(Average values for 1967-1969)

Country	Per capita GDP US$	Crude Steel (Kg)	Aluminium	Copper	Lead	Zinc	Tin
ARGENTINA	853	91.0	1.16	1.73	1.610	1.102	0.076
AUSTRALIA	2503	468.5	8.047	5.39	8.636	0.331	0.33
AUSTRIA	1604	283.5	9.10	4.465	3.151	3.306	-
BELGIUM-LUXEMBOURG	2174	401.0	16.52	11.465	5.028	13.361	0.283
BRAZIL (a)	326	51.0	0.90	0.512	0.301	0.482	0.024
CANADA	3234	469.0	10.02	10.354	2.959	4.979	0.215
CHILE	609	71.0	-	2.40	-	-	-
DENMARK	2620	346.0	1.40	-	3.836	2.020	-
FINLAND	1861	281.0	2.62	6.00	-	1.312	-

Kg Tin	Country	Kg Crude Steel	Per capita GDP US$
0.209	FRANCE	359.5	2556
-	GREECE	95.5	856
0.008	INDIA	12.0	88
0.117	ITALY	323.5	1430
1.224	JAPAN	501.0	1413
0.034	MEXICO (a)	73.5	557
-	NEW ZEALAND	267.5	1938
0.351	NETHERLANDS	341.5	1968
-	NORWAY	375.5	2398
-	PORTUGAL	65.5	543

Aluminium	Copper	Lead	Zinc
6.37	5.193	3.613	4.292
1.54	-	-	0.640
0.23	0.083	0.090	0.151
4.17	3.339	2.542	2.928
6.41	6.579	1.750	5.181
0.53	0.969	1.451	0.312
-	-	-	2.469
12.67	2.729	4.039	2.703
12.89	3.710	-	5.351
-	0.922	-	0.526

Tin (Kg)	Country	Crude Steel (Kg)	GDP US$ (Per capita)
0.085	SOUTH AFRICA	187.0	738
0.052	SPAIN	187.5	833
-	SWEDEN	603.0	3311
0.142	SWITZERLAND	349.5	2719
0.927	TURKEY	25.0	382
0.315	UNITED KINGDOM	404.5	1926
0.288	UNITED STATES	560.5	4300
0.193	FED. REP. OF GERMANY	523.5	2275

(a) Average of 1967 and 1968 figures

Aluminium	Copper	Lead	Zinc
1.44	1.549	0.746	2.350
3.11	2.476	1.979	1.890
8.10	10.924	6.898	4.388
11.70	6.109	3.595	4.398
0.37	-	-	0.188
6.83	9.646	4.990	4.959
17.25	8.950	5.431	5.900
8.84	9.761	4.749	5.883

Table 2. Forecast of per capita consumption of metals by selected countries and regions in the year 2000

		Per capita consumption (kg)			
	Region	Steel	Aluminium	Copper	Zinc
1	Japan	710	20.24	10.50	6.83
2	United States	890	52.25	14.63	9.41
3	USSR	850	17.47	7.84	3.92
4	Western Europe	710	20.24	10.50	6.83
5	Other developed countries	680	22.32	11.98	8.58
6	Eastern Europe	610	13.87	5.41	5.92
7	Latin America	100	1.72	0.91	0.95
8	China	60	0.79	0.63	0.54
9	India (high growth)	51	0.98	0.44	0.70
10	Asia	30	0.50	0.22	0.31
11	India (low growth)	26	0.51	0.20	0.32
12	Africa	20	0.24	0.16	0.07
	World	240	7.27	3.06	2.09

Source: Lahiri, A., Conservation of Mineral Resources in Commerce, Annual Number, 1976, pp. 47-49.

Table 3. Important targets for materials technology for development

- Genetically engineered plants to absorb nitrogen directly from air.
- Genetically engineered plants with stronger timber and fibres which can be pyrolized to form high-performance reinforcing fibres and carbon-carbon composites.

  Microbial processes to extract metals from ores and ocean nodules, and to remove sulphur and silica from coal, bauxite and other minerals.
- Microbial processes to extract fibres and ultrafine ceramic particles from agricultural products and wastes.
- Solar photovoltaic materials with increased efficiencies and reduced costs; solar furnaces for processing materials.
- Materials for fusion energy.
- Membranes from polymers, ceramics and composites offering lower costs and increased performance in water purification.
- Improved and inexpensive materials for housing based on abundant or renewable resources such as sand, clay, rock, stones, laterites and plant-based materials.
- Composites and ceramics with improved performances based on abundant elements such as aluminium, silica, carbon, oxygen, nitrogen and plant materials.
- Direct reduction of iron and aluminium using low energy processes drawn from solar and biomass energy.
- Recyclable materials with cascading downgraded applications offering longer life and resistance to corrosion, oxidation, wear and fatigue.
- Rapidly solidified materials for reducing energy losses.
- Surface and interface processed materials with tailored structures and properties to meet specific needs.
- High performance nano-structured materials, non-equilibrium and metastable structures.
- Room temperature superconductors.
- *In situ* polymer composites.
- Tough ceramics.
- Net shaped materials fabrication.
- Parts consolidation through single step moulding of complex shapes.

- Industrialization of developing countries will further support the consumption of traditional materials.

- Absence of technological assessments using local expertise is a major reason local resources have not been developed for local needs. Many decisions to establish manufacturing industries in developing countries were based on feasibility studies that used inadequate data. This undermined their conclusions and led to negative effects on national development.

- Priority for research and development should be given to business-oriented research ideas. Research staff must include economists and/or technical researchers with adequate understanding of economic principles; their task is to assess the economics of research and technical development.

- Large production units are not always necessary, particularly when considering speciality materials.

- Policies require a "critical mass" in order to be effective. This applies to several levels. Laboratories may not be large enough and lack the material resources necessary for effective research and development in new materials. National research and development potential as a whole may be limited through the lack of people with sufficient experience and imagination or by the restricted size of potential markets.

- The minimum conditions, e.g. facilities for materials testing and quality control, do not exist in many countries.

III.4 -Alternate routes

Several routes have been taken in the development of an infrastructure in materials. In the western industrialized countries, including the USA and Europe, the infrastructure and the production and consumption of materials evolved over several hundred years. The result is a logical sequence of teaching, research, development, small-scale and large-scale production. Formal teaching goes back two hundred years and evolved through courses in applied science and technology, special courses in metallurgy and ceramics, and more recently in materials science and engineering. Today over fifty US universities offer education in materials up to Ph.D. levels. Production evolved simultaneously from individual blacksmith shops, foundries and pottery producers, through family firms, to companies with large integrated plants to making steel and other materials, eventually emerging as multinational corporations.

Recent years have seen a decline in both large integrated steel plants, and large private sector materials research laboratories. There has been an increase in the acquisition of overseas materials manufacturing companies, the import of materials from other countries, medium-scale flexible manufacture and the use of private consultants and small privately-owned service laboratories.

The professional societies evolved from groups such as the Heat Treaters Society, through the American Society for Metals, to ASM INTERNATIONAL, a body whose 55,000 strong membership increases the scope in materials as well as in geographical coverage.

In contrast to the USA and European experience, the other countries evolved their materials capabilities over a much shorter time span. Japan, for example, consciously and therefore quickly imitated United States production practices in materials, improving on them and increasing their scale. This was followed by improvements in infrastructure for teaching and research, with the result that today Japan is viewed as leading the world in research and production of certain advanced materials such as engineering ceramics.

Some developing countries are taking another approach. Brazil, for example, set up materials production plants based on local mineral resources and imported technology. This was automatically followed by the establishment of teaching and research infrastructure to fulfill the manpower needs of the manufacturing plants. (A similar experience of the Republic of Korea is discussed later in this chapter).

India, on the other hand, emphasized the building of an indigenous capability in teaching, research and development from the start, while simultaneously establishing materials manufacturing facilities in the public and private sectors. As a result, the training, teaching, research, development and testing facilities in India for materials match those anywhere in the world, even though the production of materials lags behind countries like Japan and the Republic of Korea. India has also well established professional societies as for instance the Indian Institute of Metals with 600 members and publications covering metals and scientific development. India has over twenty departments in universities and institutes awarding degrees up to the doctorate level. There are several national laboratories (some deploying a staff of more than 1,000) including the National Metallurgical Laboratory, the Central Glass and Ceramic Research Institute, and the Central Building Research Institute. In addition India has regional research laboratories at Trivandrum, Bhopal and Bhusbaneshwar, all researching local materials. Planning for materials production is done by the National Planning Commission and the Ministry of Steel and Minerals.

At the other end of the scale, in certain raw material producing countries, like some copper-mining countries of Africa, mining is done by foreign companies or with foreign collaboration, and there is no commitment to build up any significant technical infrastructure.

No matter which route is taken to developing the infrastructure for materials , access to modern components, teaching institutes, research centres, professional societies, information and data bases and mechanisms for materials policy formulation is essential if developing countries are to achieve equivalent levels of production and consumption of modern materials.

III.5 UNIDO Activities in the Field of Materials and Related Technologies

UNIDO has long been conscious of the importance of materials, both as inputs to the industrialization process and as outputs of industry to other economic sectors.

The activities undertaken by the Organization include:

Publication of a quarterly current awareness bulletin, Advances in Materials Technology: Monitor;

Technical co-operation with developing countries on a wide range of materials, and establishment of materials technology centres - including steel, cement, paper, plastics and building materials, as well as some of the newer materials, such as carbon fibres;

System of Consultation meetings, including building materials, wood, non-ferrous metals, and iron and steel; studies in this context include, for example, research priorities for building materials;

Industrial and technological information activities including information packages, profiles, dossiers and directories;

Assessment of the technology trends, in particular materials. Areas studied include basic raw materials, the main classes of engineering materials and new developments such as materials developments for biomass utilization and space-related technologies.

IV. ROLE OF MATERIALS IN DEVELOPING COUNTRIES

The success or failure of many technologies depends heavily on the materials involved. Their selection, utilization, performance and reliability contribute towards the necessary credibility of a given product.

Traditional materials, such as stone, wood, the common metals and cement have been the basis of economic activities since the beginning of civilization.

New materials, in a broad sense, can be viewed as substances, or a combination of these, known or developed from first principles, to the preparation, fabrication and utilization of new or old constituents, yet always presenting new criteria in their build-up. As such, there is an explicit utilization of innovative process development and manufacturing leading to create quality and reliability of use. Most of the developing countries, however have missed out on the scientific and the industrial revolution of the last 300 years to varying degrees, including the revolution in materials technology. This has resulted in the lack of availability of materials per capita in developing countries both in quality as well as quantity, as compared to the availability of materials in the advanced countries.

The average availability of manufactured materials and energy per capita in the developing world is often one hundred times less than the advanced countries. In addition the cost of materials in relation to incomes in developing countries is very high, resulting in a further inequitable distribution of materials between rich and poor. In this context, the directions in which materials science and technology should be used to meet the needs of the developing countries have not received the necessary attention either from the developed or the developing world.

IV.1. Natural resources utilization trends

It has been calculated that the amount of natural resources consumed after World War II is equal to the amount of raw materials and energy used since the start of history up to 1945. However, in the 1970s the pattern of constant growth of raw material consumption rapidly changed.

Growth of Natural Resource Consumption

(per cent)

Product	Period	
	1966 - 1973	1973 - 1980
Crude oil	70	7
Industrial minerals	29	16
Metallic minerals	54	7

Source: IM, February 1987

The reasons for this interesting development are several:

- replacement of metals by plastics, ceramics and composites
- better utilization of materials generally
- environmental pressures
- recycling.

The demand for industrial minerals grows in line with industrialization. The more developed a country, the higher the share of industrial minerals in that country's extraction activity.

The pattern of future demand for individual non-metallics will be influenced by:

- the return of the crude oil shortage in the 1990s: this will stimulate drilling activities and thus the demand for bentonites and barytes:

- Increased use of low grade coal to generate electric energy: desulphurization processes will increase the demand for limestones and gypsum:

- Increased demand for plastics, especially for new grades using mineral fillers as functional components: e.g. processed kaolins - materials with defined properties;

- Growing importance of zeolites and their synthetic production from kaolins and perlites;

- Increased consumption of paper, generating demand for mineral fillers;

- Developments in advanced ceramics leading to increased demand for smaller quantities of very pure materials extracted from industrial minerals such as monazite, kaolin, silica, talc, wollastonite, bauxite etc.

World economic forecasts for the consumption of metals and therefore metallic minerals, over the next few decades indicate relatively modest but nevertheless positive rates for metals such as iron, copper, tin and lead. These rates will vary between 1 and 3 per cent. Consumption of aluminium, chromium and nickel, and metals used in the manufacture of special steels, is likely to increase at rates above 3 or 4 per cent. Demand for metals widely used in areas of high technology - columbium, titanium and gallium - will be in excess of 5 per cent.

Although the industrialization of developing countries will further support the consumption of traditional materials, the spread of new technologies will probably reduce the extent of this source of increased demand in comparison with that from the industrialized countries at similar stages of development.

IV.2. Upgrading, substitution and recycling

The declining growth of demand for materials in general has been due to:

Substitution of one material for another, slowing down the demand for particular materials;

Economies in the use of materials design and process improvements, and reduction of per unit energy cost;

Saturation of markets; and

Emergence of knowledge-intensive and service industries and substitution of electronics for earlier electromechanical functions.

Though the growth of demand in developed countries for basic materials such as steel, cement, paper, aluminium, ammonia, chlorine and ethylene is levelling off, such materials will continue to be important. Increasing cost of production of basic materials in some developed countries has also led to off-shore manufacturing, to production of speciality products and to secondary processes, such as recycling and the use of scrap.

Trends in materials consumption in developed countries are not necessarily followed in the developing countries. In many of the latter industrial development is at a relatively early stage and consumption is expected to grow significantly. At the same time energy efficiency has often not been pursued and design has not emphasized saving on the use of materials. Developing countries that produce materials such as copper and sugar have been affected by substitution processes in regard to their exports. In contrast only a limited amount of substitution of imported materials has taken place. Nor have the implications of new technologies and new materials for the industrialization of the developing countries been well understood. In short, it is premature to talk of "dematerialization" of the economies of developing countries.

The economy of several developing countries is closely linked to exports of minerals that are threatened by new technologies, for instance copper ore from countries in Africa. The development of fibre optics, which replaces copper in telecommunications, means that materials science and technology should be directed towards finding new uses for such resources; otherwise the economies of those countries will collapse and a global advance in materials science will be locally counterproductive.

Recent years have witnessed considerable progress in recycling. This also has implications for the use of resources, requiring new strategies for the design of all kinds of technical products. For example, the structure of the materials mix in these products should be such that they can be easily separated after use into the different materials classes.

IV.3 New materials in the context of developing countries

New materials development is primarily tailored to:

(a) Creating materials with more rigorous specifications; and
(b) Substitution of vulnerable or critical ores or metals.

Development of materials with more stringent specifications, either for novel or old applications, is the goal of research and industrial facilities all over the world. Market research is opening up opportunities in high technology fields, such as aeronautics, information, microelectronics, etc.

Substitution of vulnerable or critical ores and/or metals is promoted especially by governments in industrialized countries seeking to reduce the dependence of their economies on traditional sources of supply.

In both cases the underveloped economies tend to suffer. For higher specification materials they either have to rely on second hand materials or to import process or product technology to match new developments. In the second case, it is often that the metal or ore being substituted is a good export item of an industrializing country.

The problems faced by developing countries are therefore not trivial. By exporting commodities, they have to secure their balance of payments and prepare themselves to deal with the introduction of new materials in their own domestic economies. Such new materials developments, viewed as an amelioration of the raw materials crisis of the industrialized countries, may thus deepen the economic crisis for the developing countries if no corrective action is taken.

In future, many of the advances in new materials will reach the developing countries through changes in the pattern of new materials trade and changes in the use of materials in their economies.

IV.4 Materials Technologies for Developing Countries through High Science

Materials processing needs to be driven in the direction of near net-shaped components and low energy consuming processes which can generate employment in developing countries. Computer-aided design and simulation quantities of materials will suffice. However automation and robotization in developing countries should be used only selectively and where absolutely necessary in order to obtain quality and realiability. And while the scientific rigour and information input that goes into materials processing should be as high as possible, the actual process should be as simple a technology as possible, consistant with reliability and maintainability in the most primitive developing environments.

Materials in the context of development should be made as rapidly as possible using local resources, local manpower, and simple technologies which can be maintained and established in the developing countries without vast inputs of capital. Large numbers of traditional materials and processes, many of which have been used in the developing countries for decades and centuries, can be upgraded by inputs of modern materials science and technology.

Housing remains one of the most important problems of development due to the lack of availability of materials. One major challenge is to reduce the cost of materials for housing and to increase the performance of construction materials, particularly those based on local renewable or abundant resources. Of high priority here is a greater application of the most modern and vigorous materials science and technology of alumino silicates, earth, stone, laterites and clay-based products which can be readily made everywhere. For instance laterite is abundantly available in many developing countries and is used for the primitive construction of houses. Input of modern materials science could upgrade it to a modern construction material. The performance of bricks from common clay could be improved, biomass or solar energy sources could be developed to fire them or low temperature binders and sintering agents could improve conventional firing. Another area is the application of modern materials science and technology to renewable resources, particularly locally available plant-based resources, such as bamboo, Impoema carnea, fibres from plants such as coconut, sisal, banana, sunhemp, grasses, and large agricultural wastes like paddy, and wheat straw. Recent work on the structure and properties of natural fibres and shrubs, and synthesis of composites using these materials in India point to the enourmous potential of these materials.

For their economic growth, developing countries require positive materials development and utilization activities. At the same time, the potential of the new materials for development purposes have to be identified and utilized.

However, any concerted action, particularly of a policy nature, is difficult for several reasons:

Number and variety of materials and composites;

As intermediates many materials are inputs to a variety of final products;

Substitution of materials is a result of techno-economic considerations carried out by different enterprises over a period of time; and

Different materials may be critical for export or import purposes for different groups of countries.

Among possible actions that can be taken by developing countries one of the first should be to monitor and assess the implications of the changing scene of the development and use of materials. Particular attention should be paid to the trends in the substitution of materials, both to conserve scarce materials and to study the implications for exports of their own materials.

The developing countries have to be more sensitive to the fact that there is room for a choice of materials to be used in producing several products. They should also take measures to promote economy in the use of materials and conservation of material sources. At the same time, increasing efforts have to be made to reduce the energy content in processing and use of materials.

Developing countries' technological capabilities for development, testing and use of materials have to be built up, including their institutional and human resources. The process of diffusion of new materials into their economies has to be studied to see how the process could be accelerated or arrested in line with overall socio-economic development objectives.

A shortage of cement and its high price are major barriers to increasing the supply of housing in developing countries. Greater attention to rice husk ash, which is a very major resource in the developing countries, fly ash and mineral waste type materials would increase the volume of cement and bring down the cost of new high-technolgy cements such as zero defect cement, rapid setting cement, chemically-bonded cement, fibre-reinforced cement, the prices of which are presently beyond the reach of most people in developing countries. Millions of people in developing countries use plant-based materials like coconut thatch for roofing. In their natural form such materials provide neither adequate protection from nature nor are they long lasting. Inputs of modern materials sience and technology could increase their life and performance by making them more resistant to nature. Recent work in India has demonstrated that the application of modern materials science can significantly extend the life of coconut thatch roofing and making the roof resistant to fungus and fire.

These examples of the potential application of materials science to very abundant natural resources have one thing in common: they have not received any scientific input, since they are resources of little interest to the developed countries, which have most of the capabilities in materials science. The limited work in India on coconut fibres, coconut thatch, sisal and synthetic fibres demonstrates that these resources provide a challenge to materials science and that scientific enquiries can be on a level with those into space age materials.

A key goal of the technologies developed by the application of high science for developing countries, is that they should be simple and reliable, maintainable in the primitive environments of most of the developing countries. This requirement of high-science, reliable and simple technologies, often makes the task more challenging than that of adapting technologies obtained from developed countries. Responding to the local needs and constraints of developing countries sometimes provides opportunities for highly creative outputs, for example the recent development of a foundry for making metal matrix composites.

IV.5 Development examples of the Republic of Korea and Brazil

The infrastructure required by developing countries to overcome the above problems are discussed in detail in chapter V. Although the infrastructure necessary to achieve the requisite levels of production and consumption of materials does not exist in most developing countries, some like the Republic of South Korea and Brazil are taking significant steps in that direction.

The Republic of South Korea as a medium-sized developing country with minor natural resources, started initially as an imitator. Over a long period it has made considerable efforts to improve education in all areas and to lay the foundations for a techno-scientific infrastructure. The country's strategy is aimed at developing industrial production that concentrates on technology-intensive products. The importance of raw materials and labour-intensive industries (steel, basic chemicals and textiles) will decrease; other industries, like electronics, mechanical engineering and the automotive industry, will grow faster than average. In addition, product-oriented services will be further developed.

The main building blocks of the strategy are as follows:

- So-called "economies of scope" - synergistic effects, brought about by a simultaneous development of strategic industrial sectors (electronics, mechanical engineering and the automotive industry) and product-oriented services (communications, banking, insurances, contract research, marketing organizations);

-Selected, goal-oriented import of "best practices" technologies;

-Rapid development of R+D departments in large companies;

-Completion and strengthening of industry-oriented research institutions;

-Promotion of research in industry-strategic areas such as semiconductor development and flexible fabrication systems;

-Recruitment of South Korean managers with long experience in top positions in US companies and research institutions;

-Mobilization of venture capital;

-Development of R+D incentive systems;

-Cautious allowance of foreign investments;

-Continuous governmental monitoring of R+D activities in industry and other economic sectors;

-Intensive consultation between government, industry and research institutes.

The approach taken by the Republic of South Korea illustrates the comprehensive efforts needed to apply advanced technologies in a developing country. It appears necessary that such countries develop a "minimum level of technological competence" in order to take advantage of the potential of new advanced technologies.

The interest of R+D institutions in developing countries on the subject of materials should be substantially augmented. Materials science laboratories may have to take a broader orientation and they should be equipped with techno-economic units so that development prospects and materials substitution possibilities are followed up to the stage of manufacture and use. Whether combined with such laboratories or otherwise, design capabilities should be promoted since material saving is ultimately a function of design. Likewise, recycling of materials should be encouraged. Recycling being viewed in a broad sense to include the use of materials now considered as waste in developing countries.

Specific areas for study include:

Alternative building materials and their use to improve housing conditions;

Advances in plastic materials and their wide substitution possibilities.This should be systematically monitored. Apart from their relevance to oil-producing countries, use of plastics could become particularly important to developing countries having large biomass resources. This requires development of a whole chain of technologies for production of plastics through the biomass route;

Advances in the use of steel and the technology for its manufacture. Some 65 developing countries are involved in steel production. Advances in powder metallurgy are of particular interest since they may make re-rolling redudant.

Substitution of aluminium by other materials. This is driven by Silicon technologies in general are important, for production of both solar cells and semiconductors.

Development in composites relevant to the natural resources and conditions of developing countries. These are of key interest in sectors, such as housing, water and sewage, and transportation.

In addition, the potentials new materials for development need to be studied systematically. For instance, some materials developed for space-related activities have also found applications in developing countries.

Brazil disposes of important world ore reserves of strategic minerals:
Quartz (95 per cent)
Niobium (86 per cent)
Titanium
Berilium
Rare earths.

Since these raw materials are fundamental for several high technology applications, there is a strong possibility that without a policy on new materials development, finished products using them will be available only through imports.

Brazil also has the scientific and technological capability that can seed such an R+D effort. Its existing professionals are qualified to undertake the initial steps towards creating new materials technologies.

Specific plans have been drawn up in the areas of steel and metal alloys, advanced ceramics, composites and engineering polymers. There are explicit state targets in each area on human resources, R+D infrastructure, short-term opportunities for R+D linked to market needs, quality assurance, assembly and production.

Opportunities in steel and special alloys include: high-purity and rolling-controlled microstructure steels; alloys of aluminium, titanium, magnesium, berylium, copper, barium gallium and lithium and high-purity gold and gold alloys for medical and dentistry applications; other noble metals for pharmaceutical and electronic applications; super alloys and amorphous alloys; high-purity lanthanide oxides; and tungsten, thalium and zirconium in pure metal form.

R+D in advanced ceramics aims firstly at improving the processing technology (i.e. control of process variables, production of ceramic powder at sintering technologies). Product development is expected to lead to isolators, ferro-electrics, piezoelectrics, semiconductors, structural ceramics and chemically-bonded ceramics.

Potential quartz and silicon products include high-purity silicon powder, fused quartz, electron and soda grade silicon.

In engineering polymers, R+D focuses on membrane production, bio-compatible materials, reinforced plastics, high-crystalline polymers, homogeneous polymeric alloys, photosensitive materials, special adhesives, engineering plastics and polymers from alternative sources.

R+D opportunities are represented by the development of low-cost fabrication methods, mica-reinforced materials, boron, carbon and aramid fibres, aluminium matrixes, apatite reinforced polyethylene, ultra-high density polyethylene, delamination control and chemical infusion techniques.

Countries of an early stage of development may lack the technical infrastructure to assess opportunities for a successful development of a natural resource or manufacturing capability. The ability to articulate the need for training and research, or to evaluate a manufacturing opportunity can be acquired only after a certain minimum infrastructure becomes available. One of the recommendations addresses this problem with the suggestion for an International Materials Assessment and Application Centre (IMAAC). Such a centre would provide market and economic assessments and technical analyses of the feasibility of specific projects. It would also help countries at an early stage of development articulate their needs for education, training, information, research, development, testing and manufacturing technologies related to materials. The centre would also find possible partners within the international community who could fulfill these needs.

V. Infrastructure for development

Access to and control of research ideas and technical processing is the basis for developing countries to exploit local resources in the ever-increasing search for materials for specific problems and products.

A second important element is correct evaluation of economic factors, with a view to not only a self-sufficiency approach but also possible exploitation of external markets.

After start-up of production, a third element becomes important, namely independent capability for materials testing, quality control and further improvement.

Both developed and developing countries have approached the above by setting up infrastructures or by seeking external or international advice. Three levels of infrastructures have been recognized as crucial for the current development of a materials-oriented policy and for its implementation:

Scientific and technical know-how

Technological and engineering capabilities

Local production capabilities.

The first level should be capable of acquiring scientific information through international networks and call the attention of the scientific community to the specific problems arising in developing countries. It must also be capable of educating local technical staff and establishing a local research activity in specific areas.

The second level should be able to implement and control those processes and manufacturing initiatives which emerge from these new advances. To this end it must be able to interact with specialized centres and apply the quality controls needed to meet demands and seek possible markets.

Both the first and the second levels must achieve a "critical mass" in terms of people and access to existing facilities.

The third level - local production facilities - depends mostly the local social and economic situation and has to be approached on a case-by-case basis.

In the context of these three levels the following sections illustrate different aspects and approaches to providing of an appropriate infrastructure. These cope either directly with the functions outlined above or with the task of providing the appropriate training for the human resources needed to fulfill these functions, or they provide access to know-how on an international and inter-institutional basis.

V.1 Centres for Materials Science

The concept of a centre can be related to three different functions:

1. A Research Centre based on scientific and analytical hardware and a resident scientific and technical staff. The interdisciplinary nature of materials research requires either that such a centre be oriented towards specific tasks (e.g. quality control of a specific

series of products), or that its facilities (and fundings) be sufficient to cope with a sufficiently wide spectrum of problems to stay abreast of current developments. (Various centres of this kind already exist, and are illustrated in the contributed papers).

2. A Co-ordination and networking Centre, a "software centre" to co-ordinate a wide spectrum of techniques and approaches distributed amongst a number of small-sized research groups operating in specific fields. Co-ordination must ensure good collaboration and exchange of ideas, as well as access to different instruments and methods. Such a centre would rely either on a financial or other authority to co-ordinate the work. It would also develop its own expertise directed at answering requests arising from the use of new or available materials in developing countries. This task is already fulfilled by funding agencies or secretariats in a number of countries; others could set up similar centres under UNIDO direction.

3. Training centres - conventional education and training in a scientific and technical field extended to include training and proper use of existing capabilities and facilities through international co-operation networks. Such networks have been set up through multilateriel programmes sponsored, for example,by UNIDO in energy conservation (in a joint programme with Czechoslovakia) and in theoretical physics (through the International Centre in Trieste). These are described in more detail in annex 2).

V.2 Professional Societies

One important new element in building materials science infrastructure in developing countries is the role of metallurgical or materials-oriented professional societies. Possibly no initiative could be more fruitful in providing a technical meeting ground for industrial, governmental, and university technologists. Formation of technical societies in individual countries should be encouraged or their role should be strengthened if they already exist.

A number of US technical societies are embarking on collaboration with other countries. ASM INTERNATIONAL is a society for engineered materials that in the past few years has increased its efforts to become truly international and now has members in over 100 countries - both developing and developed. In a number of cases, local societies offer joint memberships with ASM INTERNATIONAL. The Society produces handbooks (including a well-known metals handbook series now being supplemented by handbooks in composites, plastics and electronic materials), home study courses, in-plant courses, video courses, computer software for materials selection, magazines and abstract services. The educational information is arranged in such a way to permit a technical person who is not necessarily a skilled educator to become familiar with the material and to teach it to others. A handful of members of the Society in any given country can thus have a large impact by teaching subjects varying from the fundamentals of metallurgy to plastics, ceramics and advanced composites. Such courses could be taught in-plant, through university extension or at special sites arranged by the local society. Courses for various skill levels are available, i.e. for training engineers or technicians.

Other materials societies in the USA also encourage interaction throughout the world. These include the American Ceramic Society, the Materials Research Society, the Metallurgical Society, the Society of Manufacturing Engineers and the American Society for Testing and Materials.

Another mechanism for introducing educational material to a developing country relies on recently retired technologists from industrialized countries who may be willing to volunteer time to teach such courses if their travel expenses are defrayed.

V.3 Workshops and Exchanges

An activity that can prove crucial in implementing and strengthening international co-operation is the organization of workshops and exchange of people. This should be aimed specifically at establishing direct contacts between people who are active in different developing countries and who constitute a network of interlinked focal points.

Continuous updating of the various options which emerge in a materials-oriented activity is necessary to complement training and co-ordinating activities. The best way to achieve this is exchange and direct comparison of ideas and experiments both between developing countries or between centres in developed and developing countries.

Workshops are also useful for implementing bilateral co-operation.

V.4 Listing of experts

An important tool to facilitate international co-operation would be a roster of experts that are both acquainted with the most advanced know how on materials science and engineering, and posess as well the flexibility and ingenuity required to suggest or follow-up applications of advanced science to specific problems arising in matching developed country needs and resources. Such a roster could be implemented on the basis of previous experience in specific materials and technological fields by UNIDO.

V.5 Information exchange and flow

Within UNIDO itself, the Industrial and Technological Information Bank (INTIB) acts as an information catalyst, operating a question-and-answer service, acting as a referral point and as a disseminator of technological publications originating from UNIDO. It acts also as an interface between UNIDO partners in developing countries and the wealth of information maintained by UNIDO through its information systems, mainly through its Industrial Information System (INDIS), Technological Exchange Information System (TIES), Investment Promotion Information System (INPRIS) and the network of INTIB information sources on selected subjects on industry in developed as well as in developing countries.

INTIB has an important role to play as to providing developing countries with information related to design, production and utilization of new materials and related advanced technologies. In particular, special databases for some new, as well as traditional materials could be established and on-line communication with existing specialized databases created to increase the quality and volume of information to be sent to developing countries. INTIB's publications, such as Guides of Information Sources, Directories of Institutions and Information Dossiers on new technological developments are of interest to developing countries giving them additional possibility to acquire information on materials and related technologies.

Annex 1

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