National Development Vision: Materials[1]

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Abstract

The beneficiation and development of new materials is critical for economic growth and competitiveness of a country. In recent years, the research and development has changed the complexion and use of materials in many industries, particularly in the areas of defense, electronics, engineering, transport, energy and sports. The critical issues faced by Pakistan are development of materials utilizing the indigenous resources, beneficiation of minerals and development of new materials especially the composites. Pakistan has a strong mineral base as compared to many other developing countries. However, the country has not been able to extract maximum potential benefits from its mineral base. Focused efforts are required for the improvements and development of new materials. The critical materials included in the study are: Iron ore for the production of steel, copper, magnesite, phosphate, silica, china clay, gypsum, and others. The study proposes the development of composite materials like Polymeric materials, GRP and other composites. Following set of required actions are suggested for achieving the objectives:

1. Acquisition of technology exploiting domestic reserves of iron ore for the production of steel,
2. Establishment of mini steel mills utilizing this technology at various sites like Nokundi, Kalabagh and others,
3. Establish research centre for copper and other precious metals,
4. Establish Centre for the development and improvement in refractory bricks like magnesite refractory bricks,
5. Promotion of research on gypsum,
6. GRP/FRP development centre for development of composite materials
7. Establishment of Institute for theoretical research on materials,

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8. Opening up of departments for advanced studies in materials in various universities around the resource rich sites,
9. Opening up of Centre for Development of polymeric materials,
10. Centre for development of photonic materials,
11. Research and development for exploitation of resources of gemstone, and
12. Establishment of Geo-data and Geo-mapping Centers.

All these efforts are expected to enhance the productivity and efficiency of the materials that will result in higher and diversified economic growth.

1. Introduction

Availability of materials and development of new materials is an important source of productivity growth. The development of new materials has changed the complexion and pace of economic growth, particularly in the area of defense, electronics, engineering, transport, energy and sports goods. For the development of new materials greater emphasis is on property attributes of materials, such as efficient design, high strength to weight ratio, lower energy consumption and higher value addition in production. The availability and improvements of existing technology and development of new technology are critical for the development of new materials. However, the critical ingredients for the development of this activity are strong base for research and development (R & D), qualified and skilled manpower, and availability of raw materials, financial resources and other infrastructure.

In this paper, we propose strategies for the development of selected materials that are critical for the economic growth of Pakistan. The development of existing and new materials depends critically on the availability of basic materials (basically from mining) and capability to develop new materials (particularly the composites).

2: Geographical Mapping:

In order to extract maximum benefit from the vast mineral resources available in Pakistan, geological mapping is an important prerequisite. It also improves the profitability and reduces the element of risk for new investment. Currently, only 33 percent area of Pakistan has been mapped. For this purpose it is important to establish a remote sensing center for producing accurate maps. Mines department at the Federal and Provincial level, Geology Departments in Universities, and SUPARCO can play an important role. (see Table 1).

Table 1: Geological Survey of Pakistan

Action	Agency	Time	Cost	Benefit
Geological Mapping of Pakistan	PMDC, Universities	5 years	Rs. 450 million	Reduction in risk for new exploration activities.
Exploration Activities	PMDC	Continuous activities	Will vary with time and nature of exploration	Increased availability of improved inputs for industrial growth.

3: Strategies for Exploration of the Mineral Resources:

Keeping in view the importance of materials in industrial development, the emphasis is on the development of materials using indigenous mineral resources. A brief overview of the mineral categories and their industrial use after beneficiation is given in Table 2. Most of these minerals are available in Pakistan. However, testing, grading and acquisition of appropriate technologies are required for their beneficiation and efficient utilization. Following critical issues are identified for intervention:

a) Utilization of indigenous raw material;
b) Beneficiation of minerals; and
c) Development of new materials

Given the resource, infrastructure and human resource constraints, it may not be possible to exploit simultaneously all the mineral resources available in the country. Therefore, we have selected a few minerals for discussion below.

Table 2: Property Class cum End-Use Classification

Principal Property Class	Industrial End-Use and Typical Commodities
CHEMICAL MINERALS	Chemical Industry: borax, bromine, salts, chemical grade chromite, fluorspar, ilmenite and other titanium minerals, lithium minerals, phosphates, sodium carbonates, sodium sulfate and sulfur; Fertilizer Industry: phosphates, potash, sulfur, limestone, dolomite and gypsum; Ceramics Industry: ball clay, bauxite, borax, refractory-grade chromite, dolomite, feldspar, fire clay, kaolin, kyanite, limestone, lithium salts, magnesite, silica, soda ash, wollastonite and zircon; Metallurgical Industry: cryolite, fluorspar, burnt lime and limestone.
PHYSICAL MINERALS	Structural Minerals: absestos, cement, gypsum, lightweight aggregates, perlite, sand and gravel, stone and vermiculite; Extender and Filler Pigments: iron oxides such as ochres, limonite, hematite, siderlite, pyrite, magnetite and goethite; Abrasives: silica sand, corundum, emery, garnet, industrial diamonds, pumice, quartz; Process Aids: baryte, bentonite, diatomite, kaolin, lithium minerals, perlite; Foundry Minerals: silica sand, zircon, olivine sand, chromite, staurolite; Industrial Gem Materials: diamonds, rubies, sapphires; Electronic & Optical Minerals: quartz, calcite, mica, apatite, fluorite, halite.

Source: Noetstaller Richard (1988). Industrial Minerals. World Bank Technical Paper Number 76.

3.1: Steel Using Indigenous Iron Ore [2]

Currently the production technology in steel industry needs high quality iron ore that is not available indigenously. The dependence on imported inputs raises the concerns about its availability at affordable prices. The production technologies that can use indigenous iron ore are available but are not used in the country. This requires action to acquire technology, and establishment of small steel mills using indigenous iron ore.

Iron ore is basic raw material for the steel industry. However, currently the domestically available iron ore is not used in steel production because the production technology adopted for the production of steel requires Iron Ore of different grade. Three types of iron ore are available in Pakistan:

i) Sedimentary found typically at Kalabagh and D.G. Khan. These are of low grade containing 30-34 percent iron and 21-24 percent silica.

ii) Volcanic deposits at Chilghazi, Chgendik and Pachin Koh, contain 40-50 percent iron and 12-20 percent silica.

iii) Hydro thermal

According to Pakistan Economic Survey (2002/03), Pakistan has over 430 million tons of iron-ore reserves. The extraction peaked in 1999/2000 with 45,980 tonnes (000) from only 318 tonnes in 1990/91, but declined to 4,942 tonnes (000) in 2001/02. However, this Iron Ore is not used in the production of steel. The import of iron, on the other hand, increased from Rs. 7,100 million (4.15 percent of total imports) in 1990/91 to Rs 24,633 million (3.88 percent of total) in 2001/02. In steel industry, the production of coke and pig iron declined by 0.37 percent and -0.27 percent per annum, respectively, but that of billets increased by 2.04 percent per annum during 1990-2002.

With the rising price of steel, domestic manufacturing based on indigenous resources is critical. The major issues are utilization of available reserves of iron-ore and up-gradation and beneficiation of available resources. For this purpose, development of steel mill using technologies for utilization of indigenous iron ore is critical. These technologies are available from Germany and other countries and a series of steel mills can be established at Nohundi, Kalabagh and other locations.

The plan for a steel mill, at Nokundi, of production capacity of 1,087,000 million tons of pig iron/1,230,000 million tons of ingots/1,072,000 mt of steel billets at a cost of Rs. 36.0 billion. The steel mill can be completed in 5 years and would provide employment to 6500 persons.[3] Currently the reserves of iron-ore at Nokundi are

[2] For Steel Mill at NoKundi, preliminary detailed report has been prepared by Mr S. H. Faruqi (Chairman Eastern Technique (Pvt) Ltd.).

[3] The possibility of five-times increase in production capacity is also worked out by Mr S. H. Faruqi of Eastern Technique (Pvt) Ltd.

sufficient for 15 years. However, the continuous exploration is required for finding more reserves in the area. (see Table 3).[4]

Change in the production technology will not only reduce the dependence of steel production on imported raw material (except for Coke), it will also result in lowering the steel price, and thus reducing the cost of production of down stream industries, particularly in the engineering and surgical goods industry. The by-product, blast furnace slag, can be used in road construction, in the production of slag cement, or in the production of slag wool for industrial and household applications.

Table 3: Steel Mill at Nokundi

Actions Needed	Agency	Time	Approximate cost	Expected Benefits
1. Establishment of Steel Mill at NoKundi	Ministry of Industries/MOST	5-years	Rs. 39 billion	Availability of steel at low price; saving of foreign exchange.
1 a: Acquisition of technology-	MOST	-do	-do	(The technology is available from Germany- the cost will depend on time of acquisitions)
1 b: Preparation of feasibility report	Ministry of Industries	-do-	-do-	Establishment of cost effective steel mill

The technology was acquired from Salzgitter, Germany in 1960s to build a steel mill utilizing indigenous iron ore, at Kalabagh. However, the project was abandoned later. The technology is still in use in several European countries. Other mineral inputs and water, except coke of desired quality, are also available at Nokundi. The coke can be imported from Iran and cost will not be high.

The mill may be set up as private-public partnership and government can provide a part of the required resources, and remaining generated through capital market. It is claimed that the steel mill will be able to pay dividends to shareholders within 5 years of its operation. Currently the estimated cost and benefits are given for the steel mill of production capacity of 1 million tons of billets. However, it can be expanded upto 5 million tons with additional costs of furnaces only.

Once the production technology is acquired and tested, small steel mills can be built in Kalabagh and other areas, to meet rising demand. (see Table 4).

[4] It is claimed that the mill can start paying the dividend to the share holders in the third year of its production. The manufacturing cost of steel billets is Rs. 3834/- per ton. The average price of Nokundi steel (billets) at Karachi is worked out to be Rs. 14,500/- per ton, where as the price of Karachi steel is Rs. 16,350/- per ton.

Table 4: Opening up of Other Steel Mills

Actions Needed	Agency	Time	Approximate cost	Expected Benefits
Steel Mill at Kalabagh (need to work on the quality of iron ore, and examine the availability of other raw materials).	Ministry of Industries and MoSt	7-10 years	Rs. 49 billion (for the steel mill of production capacity 1 million tons of billets. However, the capacity can be expanded by installing new furnaces.	Same as above.

With the rising capabilities and technology acquisition R & D efforts can be directed to beneficiation and development of other uses of domestic iron ore. PMDC and Ministry of science and technology can work jointly for this purpose. (see Table 5). Alternative technologies (Corex technology already used in South Africa and Korea) can be acquired. It will reduce the cost of producing steel that will affect the productivity in other industries, particularly in chemicals, petrochemical, automotive and other engineering goods industry, improve energy efficiency in steel production and control pollution.

Table 5: Beneficiation of Indigenous Iron Ore

Actions Needed	Agency	Time	Approximate cost	Expected Benefits
Development of Indigenous technology for utilization of domestic iron ore	PMDC/ MoST	7-10 years	Rs. 300 million	Increase the utilization of domestic iron ore. It may reduce the cost of production and save foreign exchange resources

3.2: Copper and Copper Bearing Gold and Silver

Reserves are available at Koh-I-Dilal, Ponkit, Pashin, Pharra Koh, Samkoh and other mountainous areas of Pakistan and a number of companies from Britain and Australia are already working on these minerals. However, in order to extract maximum benefits there is a need to promote exploration and processing in Pakistan. There is possibility of 80 percent value addition in copper ore that can lead to expansion in copper industry. Geological mapping and improvements in extraction capability would go a long way in the copper industry. Governments, at Federal and Provincial levels, have to come up with strategies to induct private sector in copper extraction and processing.

As mentioned earlier, copper is important ingredient for the engineering and electrical industries. The growth rate of value of production of electrical machinery was 22.0 percent during 1990/91 and 1995/96; and the growth rate of output of electrical bulbs during 1990/91 and 2001/02 was 0.93 percent and of tubes it was 2.77 percent. Options for the production of electrolytic copper, copper tubing and powder would help in increasing productivity of these industries. Furthermore, development and commercialization of copper wire can increase productivity in power sector by reducing

power losses. Therefore, the need for expanding exploration activities and establishing a Research Centre for Copper for its beneficiation is obvious (see Table 6).

Table 6: Beneficiation of Copper

Actions Needed	Agency	Time	Approximate cost	Expected Benefits
Research Centre for Copper .	MoST and Ministry of Industries	5-7 years	Rs. 350 million	Improvement in the productivity of industries, particularly industries producing electrical goods

3.3: Magnesite

Large reserves are available in Baluchistan (in Muslim Bagh and Khuzdar) and in NWFP (in Kumhar and Abbottabad). However, no plant for the manufacturing of refractory bricks is available in Pakistan, resulting in dependence on imports. The industries dependent on refractories brick include Cement, Pak Steel, Steel Melters, Foundary and other heat installing units. The heat intensity of the magnesite refractory bricks is high and it increases the productive capacity and life of kilns. Efforts are needed to acquire technology and know-how for manufacturing of magnesite refractory bricks that can help to improve productivity. Key issues include development and utilization of available reserves of magnesite and explore the possibility of technology acquisition. For this purpose establishment of a research centre is important.[see Table 7].

Table 7: Development of Advanced Refractories

Actions Needed	Agency	Time	Approximate cost	Expected Benefits
Establish Center for Refractories (magnesite and others)	MoST: PCSIR	5-7 years	Rs. 750 million	Improvement in the quality of glass and ceramics products
Development/Import of technology for refractory minerals	PMDC/ MoST	5-years	Rs. 375 million	Magnesite and chromite refractors for cement, steel and other high temperature furnaces will improve the productive efficiency.

3.4: Glass and Ceramics

Development of glass and ceramics materials is important for glass, tiles, sanitary ware, and other ceramic industries. This has important implications for the development of construction sector and industry for the production of household ware. Advanced sensors based on advanced functional ceramics can be developed. This will affect the

productivity in agriculture, avionics, space, genetic engineering, automobiles and home appliances. This depends critically on identification and implementation of standards and uniform quality like high purity silica.

3.5: Composite Materials

The composites include polymer matrix composites, metal matrix composites, ceramic matrix composites and carbon-carbon composites. The composites can be categorised in three groups.

–Group 1: Low cost and low performance for furniture making

–Group 2: Medium cost and high performance primarily used in the production of automobiles and aerospace

–Group 3: Very high cost and high performance for defence and aerospace.

Polymeric Materials are needed particularly in the plastic industry. These products and components are important for the automobile, electronics, and others. Pakistan is importing 120 plastic items and is major input in a number of industries. The development of photonic materials is critical important for the Following sectors are expected to gain: information technology, fiber optics, diagnostic applications in health care, remote sensing, and biotechnology. To improve the productivity of the sector, following actions are needed:

1) Development of polymer alloys, blends, compounds and composites.
2) Development of photonic materials.
3) Efforts to develop engineering plastic, particularly energy saving.
4) Strengthen the existing institutions.
5) Strengthening of the training institutions like Pak-Swiss training centre.
6) Establishment of centre for quality control.

Table 8: Development of Polymeric Materials and Photonic Materials

	Agency	**Time**	**Expected Cost**	**Expected Benefits**
Opening up of Centre of Development of Polymeric Materials	MoST/ HEC	5 years	Rs, 1000 million	Industrial Development
Centre for development of photonic materials	MoSt	10-15 years	Rs. 1000/- (million)	Following sectors are expected to gain: information technology, fiber optics, diagnostic applications in health care, remote sensing, and biotechnology

Furthermore efforts are required to develop composite materials like GRP/FRP. Among the composite materials Fiber Reinforced Polymer (FRP) are playing an increasingly important role in Chemical processing industries, Pulp and paper, Power, Waste treatment, and others. At present, cost of production of these materials is higher in Pakistan due to smaller market size but as the use of FRP in industrial production would rise, it is expected to result in a lower production cost.

There is a need for R & D and trained personnel, for the development of the composite material. In order to improve the research in the area and improve the capabilities of the manpower courses in Composite Engineering are needed at the graduate level. Simultaneously with R & D and training of manpower, efforts should be made to establish production capability. [see Table 9].

Table 9: Development of Composite Materials

Actions Needed	Agency	Time	Approximate cost	Expected Benefits
FRP/GRP Development Centre	MoST/PAEC	15-20 years	700 million	Improves the productivity of the industrial sector
Establishment of Institute for Theoretical Research	MoST/ Universities/ PAEC	15-20 years	400 million	Improvement is efficiency of materials

Currently, consumption of GRP is Pakistan is about 2000 Mt/yr, whereas economical size of GRP plant is 10,000 Mt/yr. However, the market size can expand with growth of industries using wood, steel and aluminum as the basic material input. With the initial investment of $ 15 million the glass manufacturers can produce glass fiber. The GRP conversion units can be established provided technology is available and they can play an important role in improving the productivity of industrial sector, particularly the SME sector.

3.6: Other Minerals and Materials

a) Phosphate:

About 24 million tons of potential reserves are available at Hazara district. Its development is critical for increasing the production of chemicals particularly chemical fertilizer. Utilizing phosphate, two types of products can be developed, viz., Milled Phosphate for direct application that is effective in acid soils, and Milled under Acidulated Phosphate is effective as chemical fertilizer. For the development of these, technology acquisition and adoption and later commercialization is absolutely important. The foreign direct investment can play an important role in this context. BRGM of France expressed interest in providing the technology to utilize this resource. BRGM, GOP and Ministry of Agriculture can contribute resources for its development.

Important chemical minerals needed in different industries are:

a) Chemical industry needs phosphate, sodium carbonites, sodium sulfate and Sulfer;
b) Fertilizer industry depends on phosphate, potash, sulfar, limestone, dolomite and gypsum;
c) Ceramics Industry needs dolomite, bauxite, fire clay, soda ash, chromite, magnesite and lithium salts.

Development of materials includes not only the development of minerals, and materials, it also includes development of complex material. These include: development of Photonic material that will affect areas like information technology, fiber optics, diagnostic applications in health care, remote sensing, pollution control and biotechnology

b)Gypsum/Anhydrite

Pakistan has gypsum reserves of 5-6 billion tonnes. It can be used as soil conditioner for the correction of sodic salts, treatment of low quality tubewell water, canal and distributaries lining with gypsum, and use in construction industry and in medicine. Pakistan extracted 328 000 tonnes of Gypsum in 2001/02 which is significantly lower than extraction in 1990/91 (468000 tonnes).

Huge quantities are available in the country. Major uses include: Sterilization, reduction in disease particularly Malaria, TB and Hepititus. Currently the production methods are defective, inefficient and expensive with no quality control.

c) Limestone for Lime

Huge quantities of lime stones are available in the country. It can be used effectively in sterlization, reduction in diseases particularly Malaria, TB, and Hepititis. Currently the production methods are defective, inefficient and expensive with no quality control.

d) China Clay

The main users of China Clay are Ceramics, Paper Filing and Coating, Paints, Rubber, Agriculture and Pharmaceuticals. Total available resources in the country are 4.9 million tons and annual production is 54000 tonnes in 2001/02. Pakistan is also importing China Clay for industrial use. In 2001/02, 15 percent of total consumption was imported. Utilization of existing reserves, exploration for new reserves to reduce dependence on imports. Need to explore for new reserves. For this purpose surveys should be conducted. For the exploration activity GOP can take the initiatives.

In order to develop these minerals, following action plan is suggested in table 10:

Table 10: Development of other Minerals and Materials

Actions Needed	Agency	Time	Approximate cost	Expected Benefits

Research and Development on gypsum	PMDC/ PCSIR	5-years	Rs. 100 million	Improve the productivity in agriculture, health and construction sectors
National Centre for Mineral Development for Industrial Chemicals	MoI and MoST (PCSIR)	5-7 years	Rs. 300 million	-do-
Opening up of Departments for Advanced Studies in Materials	MoST/ HEC	5 years	Rs, 1000 million	HRD and Rapid productivity growth in industrial sector.
Centre of Excellence for Research on Advanced Materials	MoST /HEC	5 years	Rs. 1000 million	Rapid productivity growth in industrial sector.
Upgradation/Srengthening of Laborataries in Minerals	PMDC	5 years	Rs. 350 million	Facilitate the exploitation of minerals
R & D in the acquisition of technology and training of manpower for exploiting the potential in the Gemstone	PMDC/MoI	5 years	Rs. 320 million	Value Addition and increase in the foreign exchange earnings
R & D to minimize the Environmental Losses	PMDC/ MoST/ Universities	10 years	Rs. 190 million	Help the conservation and minimize the resource degradation

4: Human Resource Development

It is mentioned earlier that exploitation of the available depends critically on the availability of appropriately trained manpower. Development of educational institutions, up to date curriculum, and qualified teaching staff are needed for improving the capability of the work force. For this purpose, in addition to the actions suggested in Table 10, up gradation and opening up of new departments at the university level are urgently needed.

Table 11: Training of Manpower

Actions Needed	Agency	Time	Approximate cost	Benefits

Opening up of Skill Development Centre	MoST/ MOE	5-years	Rs. 500 million	Increase in Productivity of the labour force
Centre for Industrial/Educational institutions/ R & D Institutions Linkage	MoST/HEC/MoI	5-years	Rs. 500 million	Commercialization of the innovations in domestic technology.

Additional Projects Needed for Development of Minerals. However, costs have to be worked out by the relevant personals.

5. Miscellaneous Actions for Development of Materials

Following additional steps for the technology acquisition and development are also necessary for rapid economic growth. The Government of Pakistan can consider following actions in the long run:

a. Steel:

1. Research and Development on near net casting for steel
2. Improvements in blast furnace technology for enhancing productivity
3. Improving energy efficiency of steel production.

Alternative technologies (Corex technology already used in South Africa and Korea) can be acquired. It will reduce the cost of producing steel that will affect the productivity in all the industry, particularly in chemicals, petrochemical, automotive and other engineering industries.

–Improvements in energy efficiency of steel production.

–Efforts to control pollution.

b. **Aluminium,** though the bauxite reserves are available in small quantity in Pakistan, following steps can be taken to improve the productivity of this material:
    1. Improvements in the technology of smelters
    2. Improvements in electrolyte cell to improve the efficiency.

c. Research on Bio Materials

1. Develop biological materials based on plants, marine life and animals
2. Establish interdisciplinary bio medical program to develop Biomaterials at the higher education level.
3. Development of biomaterial devices
4. Development of bio substitutes like blood and tissue engineering.

d. **Surface Engineering**

1. Indigenous development of thermal spray units and feed stock
2. Improvements in academic institutions to develop capabilities for characteristics evaluation and surface coating and environment friendly electroplating techniques and feed stock materials

e. **Glass and Ceramics**

1. Improvements in production technologies and use of cleaner fuel for sintering and processing
2. Develop capabilities to integrate advanced sensor technology
3. Up to date knowledge and education on ceramic materials to meet the changing needs of modern industrial sector.

f. Development of building material depends essential for civil engineering.

- For this purpose beneficiation technology for the separation of high quality lime stone and coal can play an important role.
- Processes should be modified to improve energy use efficiency.

In the long run efforts can be made for the development of nuclear materials, superconducting materials.

6: Conclusions

The beneficiation and development of new materials is critical for economic growth and competitiveness of a country. In recent years, the research and development has changed the complexion and use of materials in many industries, particularly in the areas of defense, electronics, engineering, transport, energy and sports. The critical issues faced by Pakistan are development of materials utilizing the indigenous resources, beneficiation of minerals and development of new materials especially the composites. Pakistan has a strong mineral base as compared to many other developing countries. However, the country has not been able to extract maximum potential benefits from its mineral base. Focused efforts are required for the improvements and development of new materials. The critical materials included in the study are: Iron ore for the production of steel, copper, magnesite, phosphate, silica, china clay, gypsum, and others. The study proposes the development of composite materials like Polymeric materials, GRP and other composites. Following set of required actions are suggested for achieving the objectives:

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