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MINERAL RAW MATERIALS IN AFRICA

Bauxite and development of the Aluminium Industry

Working Paper prepared by a staff member of the Mineral Resources Unit. The content of the document does not necessarily reflect the official views of the United Nations or its affiliated agencies.

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I. INTRODUCTION

1. The growth rate of aluminium has been higher than that of any other metal. World production of primary aluminium has risen from 4.13 million tons in 1959 to 9.7 million tons in 1969 and 13.7 million tons in 1977, overaging an annual increase of 8 per cent. By the year 2000 the total annual world requirement is expected to be six times that of 1969, (about 54 million tons of primary aluminium).

2. Bauxite is the principal commercial source of aluminium, generaly containing 45-60 per cent of Al_2O_3 (alumina). Off-white, greyish, brown, yellow or reddish brown, the rock is composed of a mixture of various hydrous aluminium oxides and aluminium hydroxides (primarily gibbsite followed by boehmite)and impurities in the form of free silica (SiO_2, 0 - 15 per cent), rion hydroxides (Fe_2O_3, 5-30 per cent) and clay minerals. The quality of the bauxite deposits are assessed not only by their aluminium content but also by the form in which the alumina occurs, whether gibbsite or boehmite, their silica content and other impurities.

3. Various sedimentary metamorphic or igneous rocks with 16-40 per cent alumina content (Al_2O_3) such as: nephelin-syenite and nephelin-apatite (25-33 per cent Al_2O_3), anorthosite (27-34 per cent Al_2O_3, alunite (16-18 per cent Al_2O_3), Kaolinitic clays (20-40 per cent Al_2O_3), schist with disthen, sillimanit (25-30 per cent Al_2O_3) or bituminous shales with dawsonit represent alternate sources. Except for the relatively small commercial quantity of Al_2O_3 obtained from alunit and nephlin in the Union of Soviet Socialist Republics and China, the alternative sources represent potential resources of aluminium being studied or undergoing pilot tests. It is expected that these sources will fill 5 to 10 per cent of the primary domestic aluminium demand in year 2000. The combustion products of different coals such as ash, flue-ash, etc. may also be used for alumina production.

4. Bauxite as mined contains 5 to 30 per cent free moisture and is named crude bauxite. Its beneficiation consists of crushing, washing to remove the impurities, possible separation iron minerals by various techniques followed by drying to reduce the free moisture. The degree to which a specific bauxite is dried depends in part on its handling and dusting qualities and in part on its processing requirements.

Usually dried bauxite has less than 3 per cent free moisture but still contains 10-30 per cent chemically combined water. Calcined bauxite is obtained by heating bauixte to a high temperature (1100°-1800°C) to reduce the total volatile matter to less than 1 per cent. Most of the bauxite produced in the form of dried ore is used for metallurgical purposes to produce aluminium. The calcined bauxite is used exclusively for refractory and abrasives.

5. The industrial process to produce aluminium from bauxite consists of two separate phases : the production of alumina (Al_2O_3) by hydrometallurgy and the reduction of alumina to aluminium metal by electrolysis. About 4.5 tons of dry bauxite averaging 50 per cent Al_2O_3 or 5-6 tons of crude bauxite are necessary to produce 2 tons of alumina which will yield 1 ton of aluminium metal after electrolysis.

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6. Alumina is produced from bauxite by a chemical process involving a caustic leach of the bauxite at elevated temperature and pressure, separation and selective precipitation. Other materials required in this processing to obtain 1 ton of alumina are:

Caustic soda..... 120-160 kg;	Starch..... 2-15 kg;
Lime..... 30-90 kg;	Fuel (oil, gas or coal) equivalent to 25-30 million BTU

7. Primary aluminium metal is obtained by electrolytic reduction of alumina in cells containing a bath of molten cryolite (natural or synthetic $Na_3 Al F_6$) in which the alumina is dissolved, a carbon anode and a pad of molten aluminium which serves as the cathode. Small quantities of aluminium fluoride ($Al F_2$) and flourspar ($Ca F_2$) are added to the bath.

The requirements of raw materials to produce 1 ton of aluminium metal are :

Alumina..... 1.93 ton;	Fluorspar..... 3 kg;
Cryolite..... 10-30 kg;	Anode carbon..... 500 kg;
Aluminium fluoride..... 20-50 kg;	Electricity ..... 15000 kg.

II. WORLD AND AFRICAN RESERVES OF BAUXITE

8. Bauxite is formed by the weathering of aluminium-bearing common rocks, such as feldspars or clays, in the presence of certain conditions most likely to occur in wet tropical climates. Therefore, over 90 per cent of the world resources of bauxite were found between the two tropics, in Central and South America, West Africa, South-East Asia and Australia, in areas where, during the various geological periods, there existed conditions of deep weathering of parent aluminous rocks and preservation of land surfaces.

9. In Africa the large deposits of bauxite occur in the lateritic capping of plateaux at altitudes varying from 600 to 2500 feet. The geological ages during which the deposits were formed ranged from the Upper Paleozoic (Carboniferous) to the Tertiary (Neogene).

10. Estimation of world bauxite resources. In view of the important discoveries of the last five years and in the absence of a standard classification of reserves in the countries concerned, it is rather difficult to describe the situation of world bauxite resources accurately. According to a compilation made by the secretariat of the most recent data published by competent sources (such as the U.S. Bureau of Mines, the International Bauxite Association, the USSR Ministry of Geology) on the basis of information released by the producing countries, the identified world reserves of bauxite as of January 1977 represented approximately 26,000 million tons of ore "in situ", of which African developing countries possessed 11,400 million tons or 43.7 per cent. About one third of the above-mentioned reserves could be considered as "proved", and the rest as "probable" and "possible". There also existed a minimum of 10,000 million tons of potential resources known with a reasonable degree of certitude, but identified as resources of primarily subeconomic value. Table 1 shows the distribution of world resources according to region.

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Table 1. World bauxite resources (as of 1 January 1977)

	Identified reserves		Other potential resources		Total resources	
	(millions of tons)	(%)	(millions of tons)	(%)	(millions of tons	(%)
Africa	11,406	43.7	4,000	40.4	15.400	42.8
Latin and North America	5,840	22.4	2,000	20.2	7,840	21.8
Asia (including China)	2,650	10.1	2,000	20.2	4,650	12.9
Australia and Oceania	4,620	17.7	1,500	15.1	6,120	16.9
Europe (including USSR & Eastern Socialist countries)	1,600	6.1	400	4.1	2,000	5.6
Total world	26,116	100.0	9,900	100.0	36,016	100.0

11. African bauxite resources. The particular situation of bauxite resources in the African developing countries is shown in the following table:

Table 2. Bauxite resources in African countries (as of 1 January 1977)

Country	Identified reserves (millions of tons)	Other potential resources Millions of tons)
Angola	10	?
Ghana	580	300
Guinea	8,330	1,500
Guinea-Bissau	200	?
Ivory-Coast	10	100
Madagascar	150	?
Malawi	60	?
Mali	820	1,000 (?
Mozambique	10	?
Sierra Leone	130	100
United Republic of Cameroon	1,050	1,000
Upper Volta	6	?
Zaire	50	?
Total	11,406	4,000

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The individual position of the African countries among the 12 major holdrs of reserves in the world and their share in the total world bauxite reserves is the following:

Country	Bauxite reserves (millions of tons)	Per cent of world Reserves
1. Guinea	8,330	32
2. Australia	4,560	17.4
3. Brazil	2,540	9.7
4. Jamaica	1,520	5.8
5. United Republic of Cameroon	1.400	5.4
6. India	1,400	5.4
7. Guyana	1,020	3.9
8. Greece	730	2.8
9. Indonesia	710	2.7
10. Ghana	580	2.2
11. Mali	500	1.9
12. Suriname	500	1.9

III. BRIEF DESCRIPTION OF BAUXTE DEPOSITS AND OCCURRENCES IN AFRICAN COUNTRIES

12. Angola: Ten million tons of bauxite grading 53-63 per cent Al_2O_3 were reported by USSR sources in the Donde deposit (??).

13. Benin: The bauxite indices from the Kandji area with the best occurrence at Bojecali were evaluated as non-commercial by the 1966 geological survey.

14. Burundi: A bauxite occurrence near Mpinga was evaluated by the geological survey and found uneconomic.

15. Chad: At Koro there is a deposit of bauxite in the Jontinental Terminal with 4.5 million tons grading 50 per cent Al_2O_3.

16. Congo: Indices of bauxite were reported near the Gabonese border on the Kouyi Plateau between Mossendjo and Makako.

17. Egypt: Bauxite indices reported in 1962 at Qena, south of the Bahariy Oasis, are apparently of no economic importance. Alternate sources such as steatite deposits with a suitable concentration for alumina production were also investigated in the Eastern Desert at Abu Khoug, Kahfa, Nakam and Nagrat.

18. Gabon: Indices of bauxite were reported near the Congolese border on the Mankongonio Plateau.

19. Ghana: In the southern part of the country, within a belt extending 150 miles from east to west, four groups of deposits of economic value, namely Sefwi, Nyinahin, Kibi and Mont Ejuanema, were identified and evaluated. The Geological Survey of Ghana estimated the reserves of the 13 deposits of the above-mentioned groups at 480-580 million tons of commerical reserves and 300-1200 million tons of other potential resporces (including subeconomic and speculative resources).

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Other remote deposits or indices of less importance were found at Kwanissa Odumparara Bepo, Nkwanta Bepo, Kawkawti, Sayerano, Mpuasu, Pamakrom and Awunakrom Hills.

The Sefwi Group or Sefwi Hills is composed of eight hills (Ichinoso, Kanayeribo, Supiri, Bekakhiri, Nfatalun, Afumba, Angwigare Bepo and Sumanchichi) on which the bauxite rests in the metamorphic rocks of the Birnimian separated by a layer of Kalinte, Since 1942, when the British Aluminium Company started to exploit bauxite on Ichinoso Hill, about 14 million tons of bauxite have been mined. The exploitation bears the name of the mining town of Awaso and is operated by the Ghana Bauxite Company Ltd. (55 per cent Government owned). The average thinckness of the deposit is 20 feet and the average grade 49 per cent Al_2O_3 with 3.3 per cent SiO_2.

The total current reserves of the group represent 30 million tons and the potential resources of marginal value 50 million tons.

On the Nyinahin Group the ore bodies occur as cappings on top of 10 separate hills over a length of about 20 miles. Following the last exploration carried out by the Geological Survey of Ghana, (1972-1974) the following reserves were estimated.

Nyinahin	Deposit 1.2	100	million	tons	proved reserves	(44.4 per cent)
Southern Aya	"	32	"	"	" "	(47 per cent Al_2O_3)
Aya Bepo	"	51.3	"	"	indicated "	(49.3 " " ")
Mpesaso	" 1,2,3	67.7	"	"	"	(50 " " ")
Abrantiakrom	"	21.8	"	"	"	(50 " " ")

A prefeasibility study on the exploitation of the deposits of the Nyinahin Group was conducted in 1974 and a feasibility study including the siting of the alumina plant was carried out by Chemokomplex Hungary; it seems that investments of $US 400-600 million would be necessary to implement the project.

The Kibi Group (or Atewa Range) was explored by drilling boreholes on a 500-200 foot grid from 1957 to 1973 by BASCOL. The following reserves were proved.

Atiwiredu Hill	30	million	tons	(44.9 per cent Al_2O_3)
Asiakwa South	16	"	"	(43.9 " " ")
Asiakwa North	34	"	"	(42.5 " " ")
BASOOL Area	14	"	"	

Another 84 million tons were estimated as inferred reserves. It is believed that the amount of marginal or speculative resources will be approximately 120 million tons.

The Government is studying the exploitation of the Kibi deposits for an integrated aluminium production complex, planned to produce 600,000 tons of alumina per year initially with a gradual increase to 1 million tons/year. The complex will cost a minimum of $US 600 million.

The Mont Ejuanema Group is represented by a small deposit with 1-4 millions of tons of reserves with 47.7 per cent Al_2O_3. A small scale open pit mine was worked for a few years during the Second World War.

20. Guinea: The Guinea with the world's largest bauxite resources, became the second world producer of bauxite, after Australia in 1977. The territory of the country has been intensively investigated. The reserves of the deposits explored as reported by the Geological Survey, are the following:

Boké	2100	million	tons
Fria	500	"	"
Kindia	200	"	"
Tougué	4000	"	"
Dabola	1000	"	"
Pita	200	"	"
Gaoual	200	"	"
Dinguiraye	60	"	"
Siguiri	30	"	"
Fore Carcah	10	"	"

About 11.5 million tons were obtained in 1977 from the exploration of four pit mines of the Fria deposit (Kimbo and Konkoure-Kossa mines), the Boké (Sangaredi) deposit which was to reach its maximum planned output of 9 million tons/year in 1978 and the Kindia deposit developed through a joint USSR-Guinea project (Kankan Office).

New production units are under study for the developement of the Tougu deposit (8 million tons/year), the Dabola deposit (5 million tons/year) and the area near Boké.

21. Guinea-Bissau: The Boe deposit situated between the Rio Corubal and the boundary with Guinea is associated with ferruginous laterite similar to that in the Boké area of Guinea. The reserves of the deposit are estimated at about 200 million tons grading 53-63 per cent Al_2O_3.

22. Ivory Cost: The deposits of Benene (Bongouanou) located 200 km north of Abidjan contain the following reserves in the form of bauxite layers overlying the basement:

Benene	10,700,000 tons	(53.2 per cent Al_2O_3, 14.9 per cent Fe)
Elinzue	1,300,000 tons	(43.6 " " " Al_2O_3, 29 " " ")
Ngouinou	750,000 tons	(50 " " " ")

A small deposit of 1,350,000 tons (55 per cent Al_2O_3) was identified at Gueto (west of Dimbokio), north-west of Abidjan. Major indices were reported in the Yaouré Plateau (40-45 per cent Al_2O_3) and the Orumbo-Boka Plateau.

Other bauxite indices were reported near the border with Ghana at Boundoukou, north of Sassandra (at Lahoridou and Lakoto) and north of Tabou.

23. Liberia: Some indications of bauxite exist in Maryland county in the south-east and in the Voinjama area in the north-west but the exploitation carried out did not bring economic results.

24. Madagascar: Bauxite was discovered at the beginning of the 1960s on the Manantenina Plateau is the northern part of the island with the 70 million tons of reserves of ore containing 40 per cent Al_2O_3. The deposit, which is the largest in the country, was studied for development at a rate of 45-5 million tons/year by Pechinery (1976-1977), Other reserves of about 80 million tons of bauxite were identified at Marangaka (over 40 million tons), Manakara, Farafangane, Lavaraty, with relativelly low-grade ore (38 per cent Al_2O_3) and Analavory (54 per cent Al_2O_3).

25. Malawi: Bauxite occurrences have been reported on the Mulanje Mountains and on the Zomba and Nyika Plateaux. The only commercial-grade deposit is Lichenya on the south-western side of the Mulanje (or Mlanji) Massif.

The Lichenya deposit was fully explored by pitting and drilling. It contains 60 million tons of crude baxuite ore in a layer of 4.5 m thick over an area of about 5.2 km^2. The reserves correspond to 28.8 million tons of dry bauxite grading 43.9 per cent Al_2O_3, 15.5 per cent SiO_2 and 14.2 per cent Fe_2O_3. Another 60 million tons may be considered as indicated reserves in the same area.

26. Mali: Large deposits of bauxite with potential resources of over 1,800 million tons were found:

(a) Near Bamako on the Madingue Plateau, 800 million tons with 40-45 per cent Al_2O_3;

(b) Near Balea, south of Kita 330 million tons with 40 per cent Al_2O_3;

(c) At Kenieba, 50 million tons with 46 per cent Al_2O_3;

(d) At M'Pebougou and Ouenkoro.

27. Mozambique: At Manica, near the border with Zimbabwe, a small deposit of bauxite (a product of superficial alteration associated with kaolinitic rocks) has been exploited for several decades (5,000 tons/year) for various industrial uses. The bauxite mined has the following composition: Al_2O_3, 62.3 per cent, SiO_2,3 per cent, Fe_2O_3, 2.2 per cent. Another known deposit is located at Monte Mauzo (Zambesi district) and consists of a layer 3-m thick averaging 41-53 per cent Al_2O_3.

28. Niger: Pisolitic bauxite was reported below Gaya.

29. Nigeria: An important bauxite deposit near Oshogbo was reported by the Geological Survey of Nigeria.

30. Sierra Leone: The bauxite deposits from Mokanji Hills, in exploitation since 1963, contains about 10 million tons of ore grading 60 per cent Al_2O_3.

Other smaller deposits apparently of less commercial value, are located at Gbonge Hills, Waia and in the Freetown Peninsula.

31. South Africa: Proved reserved of 15-20 millions tons of bauxite and another 20-30 millions tons of additional resources were reported in Natal Province at Weza. Indices of low-grade bauxite were also reported at Ngoma.

32. Togo: Non-commercial (?) deposits of ferruginous laterites with 46-53 per cent Al_2O_3 and 18 - 30 per cent Fe_2O_3 are located near Palimé at Mount Agou.

33. United Republic of Cameroon: The Mini-Martap deposit in the Adamaoua district located 500 km from the sea coast, with 1,400 million tons of measured reserves and 600 million tons of inferred reserves, grading 43 per cent Al_2O_3 and 3.4 per cent SiO_2, is one of the largest deposits in the world. Its possible exploitation has been studied and production may start at a possible rate of 10-15 million tons/year after termination of the trans-cameroonian railway. The amount of US$1,200 million will be available for capital investment. An intermediate solution of exploiting 1-2 million tons/year has also been envisaged.

In the same district of Adamoua, the Ngaoundai deposit has been fully evaluated and contains 100 million tons of reserves grading 42 per cent Al_2O_3.

In the Dschang sector only 150 km from Douala are found the Foungo-Tongo deposit with 34 million tons of bauxite grading 47 per cent Al_2O_3 and 3.6 per cent SiO_2, the small deposit of Bamboutos (4 million tons with 46 per cent Al_2O_3 and 4.3 per cent SiO_2) and the indices from Fokamezoun-Fokone.

34. United Republic of Tanzania: Indices of aluminous clays with bauxitic affinities were reported to the west of Mombo in the Eastern Usambara Mountains (35 per cent Al_2O_3) and in the western part of the Uluguru Mountains.

A sample of bauxite (57.72 per cent Al_2O_3 and 10.53 per cent SiO_2) was collected from a weathering zone at Amani in Tanga Province.

35. Upper Volta: High-grade deposits (69 per cent Al_2O_3) are known at Kaya, South of Kongoussi, with reserves of 5 million tons of crude bauxite.

36. Zaire: There is a bauxite deposit east of Tabela.

37. Zimbabwe: A small deposit of bauxite has been in exploitation for local use since 1963 from the mine north of Penhalonga near the border with Mozambique.

IV. WORLD AND AFRICAN PRODUCTION

A. Bauxite production

38. The African share of the world production of bauxite has increased steadily since 1946, rising from 2 per cent in the 1950s to 5.8 per cent in the 1950s and to over 15 per cent at the end of the 1970s, as shown below:

Table 3. World and African production of bauxite
(Thousands of Metric tons)

Year	World	Africa	Africa share (percentage
1946	4,563	118	2.6
1949	8,542	159	1.8
1959	23,044	456	2.0
1960	[illegible],620	1,577	5.7
1969	55,458	3,188	5.7
1970	60,632	3,284	5.4
1971	66,663	3,559	5.3
1972	69,215	3,462	5.3
1973	75,365	4,853	6.4
1974	84,252	8,640	10.2
1975	76,524	8,696	11.4
1976	79,544	11,230	14.1
1977	84,780	11,863	14.0
1978	84,147	13,110	15.6
1979	86,500 x/	13,000 x/	15.0 x/

Source: For tables 3,4,6,7,8 and 9, World Metal Statistics (World Bureau of Metal Statistics).

The major world producers of bauxite are Australia (29 per cent), Guinea (14.1 per cent), Jamaica (13.9 per cent), Suriname (6.3 per cent), the USSR(8 per cent), Guyana (4 per cent), Greece (3.12 per cent), Hungary (3.4 per cent). Brazil, India and Venezuela are countries with large bauxite deposits now being explored or developed and which will rank them among the major world producers during the next decade.

Eleven of the major bauxite-exporting countries of the world, namely: Jamaica, Guyana, Suriname, Haiti, the Dominican Republic, Guinea, Ghana. Sierra Leone, Australia, Indonesia and Yugoslavia are members of the International Bauxite Association (IBA).

39. According to the statistics of the World Bureau of Metals, the position of the African producing countries during the last decade was the following:

Table 4. Production of bauxite in Africa

Year	Guinea	Sierra Leone	Ghana	Mozambique	Zimbabwe
1969	2,459	454	269	4.4	2.0
1970	2,490	449	337	7.1	2.0
1971	2,630	590	329	7.7	2.0
1972	2,600	694	340	5.4	2.0
1973	3,800	693	354	5.6	2.0
1974	7,600	672	363	5.4	2.0
1975	7,650	716	325	5.2	2.0
1976	10,297	660	267	5.0	2.0
1977	10,841	745	275	2.0	2.0
1978	12,065	716	330	-	2.0
1979	12,136 a/	650 a/	214 a/	-	?

40. The average annual rate of increase in the world for bauxite as projected before the energy crisis was about 9 per cent. The forecast of world bauxite production was therefore 84 millions tons for 1975, 130 million tons for 1980 and 250-300 million tons for the year 2000. It would in fact be more realistic to reduce the above figures by 25-30 per cent.

41. Nevertheless, the production of bauxite in Africa increased continuously as a result of the development of the mining sector in Guinea (the annual production of the Boke-Sangaredi deposit by the Compagnie de Bauxites de Guinee was stepped up to 9 million tons) and will continue to increase. The future output of developing Africa will possibly represent about 20 per cent of the world supply of bauxite as shown in the following table:

Table 5: Anticipated bauxite production in Africa (millions of tons per year)

Country	1985-1990	1995-2000	New Mines
Guinea	20-23	25-30	Dabola (5), Tougue (8)
Ghana	2.5	5.5	Kibi (2.5 , Nyinakin
Sierra Leone	0.7	1.2	Port Loko (1.2)
United Republic of Cameroon	1-4	5	Mini-Martap (5-10)
Mozambique	-	2	?
Madagascar	2-3	5	Manantenina (5)
Guinea-Bissau	-	3	Bamako, Kenieba
Other	2	3-5	West and Central Africa
Total	27-35	52-62	

42. The investment costs of establishing new facilities for producing bauxite represent from $8 to $80 per ton/year of produced processable ore in open-cast mining $70 to $150 in underground mining excluding road infrastructure. Assuming an average of $50/ton, a capital investment of 1 billion dollars would be needed to increase the present bauxite production in developing Africa by about 20 million tons by 1990.

B. Alumina (Al_2O_3)

43. Of the Aluminium Oxide (alumina) produced in the first stage of transforming the aluminium ore in to metal, 94 per cent is used for the production of aluminium metal and the rest for abrasives, refractory and chemical industries.

The world production of alumina and Africa's share are shown in the following table:

Table 6: Production of Al_2O_3 (millions of tons)

	World (excluding Socialist countries)	Africa (Guinea only)
1970	20.96	0.610
1971	22.78	0.665
1972	23.62	0.663
1973	25.98	0.615
1974	24.34	0.656
1975	22.09	0.639
1976	22.66	0.562
1977	25.19	0.562
1978	25.15	0.622
1979	26.03	0.656

The African production of alumina shown above was obtained from the Conakry plant in Guinea with a capacity of 700,000 tons/year. This alumina was exported mainly to the European countries.

In Ghana, aluminium metal is produced from imported alumina; locally produced bauxite is exported in a concentrate which is believed to consist largely of alumina.

44. New African alumina plants are planned in connxion with the development of bauxite production, with a view to increasing the export value of the raw material, in Guinea, the United Republic of Cameroon, Ghana, Sierra Leone and Madagascar or in connexion with the availability of cheap energy and increasing domestic demand in countries such as Algeria, Nigeria and Zaire. By 1985-1990 the African production of alumina is expected to increase to 2.3-2.6 million tons/year.

C. Primary aluminium production

45. Table 7 shows the rapid growth of the world production of aluminium, a short period of decline in 1975 and the subsequent resumption of growth at a lower annual rate as well as Africa's share of production.

The United States of America is currently producing about one third of the world output, followed by the USSR, Japan, Canada, Norway and the Federal Republic of Germany which are major producers World capacity represents about 16 million tons per year. New important production facilities are under construction or in the planning stages in Venezuela, Brazil, the USSR and the Arab countries.

Table 7, World and African primary aluminium production (Thousands of tons/metal/

Year	World	Africa		African Countries			
		Total	%	United Republic of Cameroon	Ghana	Egypt	South Africa
1966	7,212	48.2	0.7	48.2	-	-	-
1969	9,625	159.8	1.3	46.7	113.1	-	-
1970	10,310	165.4	1.6	52.4	113.0	-	-
1971	10,934	191.2	1.8	50.7	111.1	-	29.4
1972	11,648	230.0	2.0	46.2	130.9	-	52.9
1973	12,724	249.1	2.0	44.1	152.2	-	52.8
1974	13,817	279.0	2.0	46.8	157.2	-	75.0
1975	12,725	275.0	2.2	51.6	143.3	5.0	75.9
1976	13,072	337.2	2.6	48.7	151.1	59.0	78.4
1977	14,220	368.3	2.6	46.2	154.1	90.0	78.0
1978	14,643	336.3	2.5	41.3	113.5	100.4	81.1
1979	15,129	401.0	2.6	44.9	168.7	101.4	86.0

46. The African producers are the United Republic of Cameroon, Ghana, Egypt and South Africa with a production capacity in 1978 under 450,000 tons/year as indicated below:

United Republic of Cameroon: 55,000 tons/year Edea, ALUCAM (Compagnie Camerounaise d'Aluminium) Smelter.

Ghana: 220,000 tons/year Tema, VALCO (Volta Aluminium Company) smelters.

Egypt: 100,000 tons/year, Nag Hamadi, smelter located on the Nile and using the power output of the Aswan High Dam; by 1985 production will be increased to 170,000 tons/year.

South Africa: 80,000 tons/year, Richard Bay/Natal, ALUSAF (Aluminium Corporation of South Africa) smelter.

47. Plans are under way to expand the primary aluminium production capacity as follows:

Algeria: A smelter with a capacity of 140,000 tons/year will be built by 1982 and a second similar one by 1990;

Libyan Arab Jamahiriya: A project is under review for a smelter producing 200,000 tons/year to be operational by 1990;

Ghana: Construction of a second smelter is under study at Tema;

Zaire: A project for an aluminium refinery has been recently approved;

Guinea, United Republic of Cameroon, Nigeria, Sierra Leone, Madagascar: projects for constructing aluminium plants in an integrated bauxite-alumina-aluminium system are in the "pipe-line". In view of the high investment costs and other economic aspects related particularly to the supply of energy and raw-matterials and market conditions, the capacities and scheduled opening dates of the new plants are established and it is rather difficult to anticipate the African production of aluminium during the 1990s. According to a scenario suggested by IDEP, production at the beginning of the next decade would be between 3.3 and 5.5 million tons/year.

D. Secondary aluminium production

48. The amount of secondary aluminium recovered from scrap represents 15 to 20 per cent of the total world aluminium supply. The "new" scrap generated from the processing of the raw aluminium stock into semi-finished or consumer products represents about 10 per cent of the primary aluminium produced and is essentially all recycled.

The "old" scrap from used manufactured products and waste is only partly recycled which constitutes a major problem of conservation of raw materials and energy. It was estimated that at 1977 current prices the recycling of an additional half million tons of aluminium per year would make it possible to reduce bauxite imports by about 2.5 million tons of bauxite, conserve at least 6.5 million Kwh and yield a savings of at least one billion dollars in capital investment.

Table 8 shows the world and African production of secondary aluminium metal:

Table 8. Production of secondary aluminium (thousands of)

Year	World	Africa (estimates)
1966	1.741	7
1969	2.271	7
1970	2.130	8
1971	2.205	10
1972	2.389	10
1973	2.727	9
1974	2.792	10
1975	2.532	10
1976	3.011	10
1977	3.153	11

49. The African plants producing secondary, aluminium are the following:

Morocco	SAMAB (Societe Africaine des Metaux et Alliages Blacs) at Ain-Seba, 200 tons/year,
Zimbabwe	Metal Sales Company at Bulaiwayo, 500/tons/year, Non Ferrous Metal Works, Pvt., Ltd. at Salisbury, 200 tons/year;
South Africa	Eight plants with a capacity varying between 200 and 2,000 tons/year producing a total of 9,000 tons/year.

V. UTILIZATION AND ECONOMIC ASPECTS

A. World and African consumption of aluminium metal

50. Aluminium metal and albys are used in many products because of aluminium's low density, high electrical and thermal conductivity, resistance to corrosion, non-toxicity, malleability and high strenth to weight ratio.

Aluminium appears to be one of the metals which will be most useful in promoting economic and social development, particularly for the African countries.

The major consumers, as in the developed countries, would be transportation industries, electrical and communications industries (cables), road building and housing industries, producers of agricultural machinery, foil and durable household goods, etc.

51. During the last decade the total world and African consumption of aluminium metal was as follows:

Table Primary aluminium consumption (Thousands of tons)

	1971	1972	1973	1974	1975	1976	1977	1978
World	10.732	11.775	13.653	13.889	11.350	13.957	14.383	15.231
Africa	93.5	104.7	108	112	111	114	126	139
%	0.87	0.89	0.79	0.80	0.98	0.82	0.87	0.91

52. The world's major consumers of primary aluminium are the United States (32.5%), the USSR (12.0 per cent), Japan (10.9 per cent), the Federal Republic of Germany (6.3 per cent), France (3.5 per cent), the United Kingdom (2.6 per cent), Italy (2.6 per cent) and China (2.75 per cent). In terms of kg per capita consumption is as follows: The United States 22 kg, Japan and the Federal Republic of Germany 15 kg, the USSR, France, Italy, and the United Kingdom 7 kg.

53. In Africa, with the exception of South Africa and to some extent the Libyan Arab Jamahiriya, Algeria, Egypt, Nigeria, Morocco, the United Republic of Tanzania and Ghana, the majority of the developing African countries consume aluminium at a very low rate usually in the form of imported semi-manufactured products.

B. Prices

54. Internationally, the aluminium price is established on the London Metal Exchange for 99-99.5 per cent ingot with the spot price expressed in £/ton and on the New York Market for 99.5 per cent unalloyed ingots in US cents/lb, the being applicable in the United States and Canada.

Bauxite prices are fixed for crude bauxite, dried and calcined bauxite or refractory grade super-calcined bauxite, f.o.b. mine of f.o.b. port of export (shipment) or f.o.b. port of import, in US$/ton. The delivered cost per metric ton is also adjusted for ore grade.

55. The average prices and their evolution are shown in the following table.

Table 10 Prices of bauxite and aluminium

	Jamaican crude bauxite US$/ton	Aluminium US$/ton New York Market	London Market
1960-1965	7.50	540	510
1966-1969	12.00	560	556
1970-1973	12.00	601	625
1974	23.20	752	948
1975	25.30	877	686
1976	27.20	978	859
1977	30.80	1.132	995
1978	34.30	1.170	1.045
1979 (6 months)	35.47	1.247	1.468

Note: Current prices in US$/ton; data from World Bank sources.

56. Changes in price of aluminiam reflect not only variations in production capacity as they interrelate with market demands but also in 1974 and 1975, the world recession, the increasing costs of petroleum and of capital investments as well as the higher bauxite price (1974). As can be clearly seen, the price of bauxite recorded a sharp increase in 1974, the year of the establishment of the International Bauxite Association and of the adoption of a new price policy.

C. Investment Costs

57. In 1972-1973, the capital investment to produce a ton of bauxite per year in open-cast mining ranged from US$17 - 28 according to the mine's capacity. In 19[illegible] it rose to US$85/ton of produced bauxite for individual projects excluding infrastructure. For underground mining the investment cost may reach US$150 per ton/year of processible ore.

58. The capital investment to produce one metric ton of alumina (Al_2O_3) per year averaged US$200 ton/year in 1972 for a 300,000 ton/year plant. At 1978 prices the investment cost rose to US$650-750 for each ton/year of capacity in an unintegrated plant.

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59. For the production of primary aluminium metal, the capital investment for the smelter amounted to only US900 per ton/year capacity during 1972-1973. At 1978 prices, the average investment cost for individual project rose to US2,800 per ton/year of capacity of aluminium production. The investment for power generation is not included in the above-mentioned costs.

60. Because of the high capital requirements and in an effort to economize production costs and increase profits, the primary aluminium industry is highly integrated and consists of a relatively small number of companies or state organizations throughout the world.

The world's major integrated producing companies are: ALCOA (United States), ALCAN (Canada), Reynolds (United States, Pechinery-Ugine-Kuhlmann (France), Kaiser (United States) and Alusuisse (Switzerland). During 1971-1972 the six above-mentioned comapnies possessed 52 per cent of the world production capacity of bauxite 70 per cent of the world production capacity of aluminium

D. Energy consumption

61. Aluminium is one of the most energy-intensive industrial products, since a high consumption of electrical and thermal energy is required from the mining of the raw material to the production of primary aluminium in raw stock and the further processing of semi-finished products. The energy breakdown is as follows:

Bauxite mining, treatment and transport	1-2 per cent
Production of alumina	12-16 per cent
Production of aluminium (Smelting Electrolysis	65 per cent
Remelting of scrap and fabrication	16-20 per cent

62. The largest percentage of energy, about 15,000 to 17,000 kwh or the equivalent of 25-30 barrels of oil or gas equivalent, is required to produce one ton of primary aluminium from alumina.

Energy consumption for alumina production is five times lower, about 3 barrels of oil equivalent per metric ton of Al_2O_3 or the equivalent of 10^6 BTU when the alumina is extracted from bauxitic ores using the Bayer process. To produce alumina from alternate sources with a lower Al_2O_3 content (such as alunite, Kaolinitic clays or anorthosite) it is to increase the ratio of energy consumption from 2.4 to 3.2.

63. Within the developed countries of the western world, the sources of energy used for the integrated production of aluminium were (in 1974):

Hydroelectric power	53.2 per cent
Coal	21.0 per cent
Natural gas	10.6 per cent
Petroleum	12.6 per cent
Nuclear	2.3 per cent
Other	0.3 per cent

In Africa, hydropower from the existing dams (Aswan in Egypt, Akosombo - Ghana, Edea - United Republic of Cameroon) represents the principal source of energy for current alumina or aluminium production. The envisaged new production units are also located in areas where hydroelectric power is currently or will be available. (Nomorona dam - Madagascar, Kpong dam - Ghana, Cabore-Bassa - Mozambique,

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Song Loulou - United Republic of Cameroon Inga - Zaire). Exceptions are the planned aluminium plants in the Libyan Arab Jamahiriya, Algeria and possibly Nigeria which may use electricity power plant generated by burning fossil fuels.

E. Environmental impacts

64. At each stage of the aluminium production process, appropriate environmental protection measures should be taken to meet the following requirements:

(i) Land restoration after mining operations and treatment of liquid effluants from ore washing.

(ii) Disposal of residual red mud (approximately 1 ton for 4 tons of bauxite) and possible recovery of some useful components during the Bayer refining process.

(iii) Adequate dust control during the calcination of hydrate to Al_2O_3.

(iv) Control of air pollution during the smelting electrolysis using fluorides (0.05 ton/1 ton of Al) and carbon electrodes (0.5 ton/1 ton of Al). The main air pollutants are hydrogen fluoride, carbon monoxide, sulphur dioxide and coal tar pitch voltiles.

VI CONCLUSIONS

65. Africa as a whole possesses about 43 per cent of the world resources of bauxite, produces about 15 per cent of the world bauxite and transform only 2.6 per cent of the world production into alumina and primary aluminium. Practically all the above-mentioned production is exported; more than half of the primary aluminium used for [illegible] is imported. Sub-Saharan Africa, where African bauxite resources and production facilities are located, is currently consuming less than 0.3 per cent of the world's primary aluminium.

66. The quality of African bauxite reserves, particularly those of Guinea (high Al_2O_3 content, 45-55 per cent, and low silica content as well as the market demand will contribute to the steady increase of African bauxite production, which may exceed 60 million tons/year during the 1990s. In addition to a substantial increase in the existing production capacities of Guinea, Sierra Leone, Mozambique and Ghana, new producers will come into the pricture such as the United Republic of Camerron, Guinea-Bissaue, Madagascar and possibly Mali, Nigeria, the Upper Volta, Liberia and Malawi.

The majority of the bauxite production (approximately 85 per cent) will continue to be exported until the establishment of plants to produce alumina and aluminium.

67. The extistence of large potential sources of hydropower as well as of available or potential reserves of fuel (gas-flared, undeveloped deposits, on the continent will facilitate the processing of the raw material into aluminium and then into semi-finished and finished products.

An important feature is that the new developments planned in Madagascar, the United Republic of Cameroon, Mozambique, Ghana, Guinea, Sierra Leone and Guinea-Bissau will be vertically integrated from bauxite mining to the production of aluminium and that the major source of energy should be hydrowpower.

In addition, Algeria, the Libyan Arab Jamahiriya and Egypt in North Africa and Zaire and Nigeria in West Africa will use their available energy potential to transform imported bauxite and /or alumina into aluminium.

68. An African production of 4.5-5 million tons of aluminium/year at the end of this century, represent about 10 per cent of the world production of bauxite or local transformation of about 40 per cent of the envisaged production of bauxite, appears possible, subject to the release of funds for capital investment not only for new plants but also for infrastructure.

The establishment of the adequate capacity for processing aluminium produced into semi-finished and finished products on the continent which may substantially increase the average consumption of aluminium up to 2-4 kg per capita in the years 2000-2020, is an important target of the Monrovia strategy for the economic and social development of the African continent.