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THE BAUXITE WASTE TAILINGS
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A NEW APPROACH TO ECONOMIC UTILIZATION OF BAUXITE RESIDUES

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This paper has been prepared without formal editing.

1. Introduction, development and application of the new approach:

On the basis of knowledge and experience collected in working with ceramics technologies, a system and method were developed to utilize large amounts of red mud in the production of ceramics. According to the Hungarian patent No. 171.820, a multi-component system can be applied permitting to increase the content of dry red mud up to 90 % in the dry ceramic mixture. This mixture yields upon firing at relatively low temperatures of 950 to 1150 °C a diverse line of high strength products, such as heat insulating bricks, heat insulating water pipes, building bricks, wall and floor tiles, low weight building materials (specific weight 1 t/m3), brickwork of foundries, surfacing materials. The additives are, in majority, wastes or refuses of other industrial branches constituting environmental problems themselves at present, e.g. flotation refuse of ore dressing, sand washing sludge, waste of plants of silicate industry and their dust, mining refuse of igneous rocks, oil shale slag, refuse of perlite grinding, dust of perlite swelling, ashes and flue dusts of power plants, loess, dolomite, diatomaceous earth, household and industrial scrap glass, zeolite, quartz sand, sandy illite refuse, etc. By proper selection of quantity, quality, grain size of the additives and of the manufacturing technologies, chemical and physical properties of the bulk and surface, technical characteristics of the end products may be optimized. Frost-resisting ceramics may also be produced. Red mud is not easily transportable in original state, however, if it is processed to mixtures at the alumina plant, it can be transported to the ceramic factories of building materials and heavy ceramics. By applying this technology the total quantity of red mud released by alumina production could be processed to valuable building materials, ceramic and other products in the majority of countries processing bauxite.

The new method was patented in Britain, Australia, the United States and a number of other countries. It was first published internationally in outline at the UNEP/UNIDO Conference on Environmental Protection for the Alumina Industry held in Paris in December 1980 and it was included into the list of recommendations adopted by the Conference. Based on this recommendation, the Jamaican Government requested first through UNIDO the preparation of a special study applied to the conditions prevailing in Jamaica.

The Indian state company, Sponge Iron India Ltd was the second for whom upon the request of the Government of India to UNIDO an application study with pilot-scale testing was elaborated in 1983, demonstrating the possibility of utilization of ore washing and gas washing sludges of a steel plant, with compositions similar to red mud, for building industrial purposes.

In 1984, the Chinese Government requested a similar study to be organized and financed by UNIDO on the elaboration of a process for the economic utilization of the so-called brown mud residues of the Shandong Aluminium Works for building material purposes.

In 1985, the Indian Government requested UNIDO again, now for the Indian Rare Earth Company, Bombay, to elaborate economic solution for the utilization of garnet sand, based on the same technological know-how. In the same year and along the same line, a study was elaborated for the Korba plant of the Bharat Aluminium Company, India, for the utilization of their red mud for building material purposes.

In Hungary, one of the alumina plants will be expanded to produce mixtures from red mud. This mixture will be supplied to a ceramics factory to produce 150.000 m^2/year ceramic tiles and 50 million pcs per year of klinker bricks. In case of conversion of the brick and ceramics industry of Hungary, to process such mixture, the total volume of Hungarian red mud of one million tons per year could be processed without fully meeting the raw materials need of the ceramics industry.

In the following, the most frequent oxides and minerals occuring in the metallurgical wastes are shown.

2. Review of main oxide constituents of heavy ceramics and their form of occurence:

Al_2O_3:

Bentonite (montmorillonit)	$CaAl_3\ [Si_8O_{20}(OH)_4].nH_2O$
Illit (hydromuskowit)	KAln $[Si_7AlO_{20}(OH)_4.nH_2O$
Kaolinit	$Al_2(OH)_4\ Si_2O_4$
Gibbsite	$Al(OH)_3\ (Al_2O_2.3H_2O)$
Boehmite	AlOOH $(Al_2O_3.H_2O)$
Diaspore	AlOOH $(Al_2O_3.H_2O)$
Alumogoethite	Fe(Al/OOH) with isomorph substitution

Sodium-aluminium silicates (sodalites), NAS

$3(Na_2O.Al_2)_3.2SiO_2)Na_2X.nH_2O$

where X may be CO^{2-} SO^{2-} OH^- AlO^-

Calcium-aluminium silicates, CAS

Tri-calcium aluminate $3CaO.Al_2O_3.6H_2O$.

Fe_2O_3

Ilmenite	$FeTiO_3$
Hematite	Fe_2O_3
Geothite	FeOOH
Magnetite	$Fe_2O_3.FeO$
Pyrite	FeS_2
Marcasite	FeS_2
Garnet (almandin)	$Fe_3Al_2\ (Si_3O_{12})$

SiO_2

Clay minerals (kaolinite, montmorillonite, illite)

Quartz	SiO_2
Sodalites	NaS

Calcium-aluminium silicates, CAS

TiO_2

Sodium titanate	Na_2O, TiO_2
Calcium titanate	$CaO.TiO_2$
Sodium-metatitanate	$NaH.TiO_3$
Ilmenite	$FeTiO_3$

Na_2O

Sodalites, NAS

Sodium titanates

Other soium salts

MgO

Magnesium-aluminium silicates, MAS	
Magnesium hydroxide	$Mg(OH)_2$
Other magnesium minerals	
Dolomite	$CaMg(CO_3)_2$
Magnesite	$MgCO_3$

CaO

Tri-calcium aluminate	$3CaO.Al_2O_3.6H_2O$
Calcium titanate	$CaO.TiO_2$
Phosphorite	$Ca_3(PO_4)_2$
Fluorite	CaF_2
Calcium-metavandate	$Ca(VO_3)_2$
Calcium-aluminium silicate CAS	
Apatite	$CA[(PO_4)_2F]$
Lime	$CaCO_3$

V_2O_5

Calcium-metavandate $Ca(VO_3)_2$

Other vanadium containing minerals

P_2O_5

Phosphorite $Ca_3(PO_4)_2$

Apatite $CA_4[(PO_4)_2F]$

CO_2

Mainly in the form of calcite and dolomite

SO_3

In the form of various minerals (alunite, sodalite, pyrite, etc.) P; Mainly in the form of apatite and fluorite C; in the form of various organic substances.

L.O.I. Crystalline water of minerals decomposed up to 1.100°C. Thermal decomposition of CO_2, SO_2 and organic substances.

3. The new compositions applied:

The maximum Fe_2O_3 content of the so-called klinker clays of high Fe_2O_3 content used in the ceramic industry has been 11 p.c. According to the technical literature materials of higher Fe_2O_3 content cannot be used for this purpose from technological point of view. This statement relates of course, to the traditional clay based ceramics production.

The author investigated and found that in spite of the high iron oxide content it is possible to produce better quality products from the metallurgical wastes and by-products than those made of classical silicate type industrial raw materials. The elaboration of the suitable optimum technology requires the chemical and mineralogical analysis and investigation of the high iron content metallurgical wastes. In addition, local availability of mining and other industrial wastes and by-products of high silicate or silica content is also necessary. In the possession of the composition data the next step is the optimization of the material composition and of the technology of production of the product. On the basis of the initial data received an optimum composition for the manufacturing of architectural ceramic products was worked out, permitting application of single-firing technology.

The optimum composition of a final ceramic product is reflected by the following percentage figures:

SiO_2	50 - 55 %
Al_2O_3	15 - 25 %
Fe_2O_3	5 - 30 %
CaO	1 - 30 %
MgO	0,5 - 2,5 %
TiO_2	0,25- 5 %
Na_2O	1 - 2,5 %
K_2O	0,25- 1,5 %

In the Table No.1, the oxyde composition of different metallurgical wastes and by-products is shown to demonstrate the extent of deviation from each other and from the optimum mixture.

In the following, examples of the initial chemical composition of some metallurgical wastes are shown against the final composition optimized for products manufactured from them within the scope of UNIDO projects.

Jamaican red mud (Kirkvine)		Optimized composition
SiO_2	3,04 %	48.64 %
Al_2O_3	13,20	11,29
Fe_2O_3	49,40	28,20
Na_2O-K_2O	4,0	2,10
CaO	9,4	6,0
TiO	7,3	4,4
P_2O_5	1,0	0,55
Firing loss	12,5	-

Table 1: Chemical analysis of muds, sludges, and waste materials of high iron oxide content

Component	Kaiser Aluminium red mud	Reynolds Hurricane brown mud	KORBA India red mud	Kirkvine red mud	Shandong Alu. Works P.R. China brown mud	SIIL Kothagudem India iron ore and gas washing sludges	IRE-OSCOM India garnet sand
Al_2O_3	15	6,31	6 - 19	13,2	5,85	13-13,9	20,6
Fe_2O_3	51,5	10,7	45 - 48	49,4	7,14	20,9-53,6	30
SiO_2	1,7	19,9	20 - 22	3,04	21,87	50,6-20	38,2
TiO_2	6,7	3,32	2,5	7,3	0,79	1,8-1,5	2,4
CaO	7	42,5	8-10	9,4	45,9	-	2,5
Na_2O	0,97	1,34	2,1	1	1,84	-	0,05

Indian steel plant sludges (Sponge iron of India Ltd. Kothagudem)

	iron ore washing sludge	gas washing sludge	optimized brick composition
SiO_2	50,6 %	20,0 %	50-55 %
Al_2O_3	13,0	13,9	18-20
Fe_2O_3	20,9	53,6	15-25
TiO_2	1,8	1,5	1,2
MgO			0,5
CaO			1-2
L.O.I.	4,7	1,9	

Indian garnet sand (Indian Rare Earth, OSCOM Plant)

	garnet sand	optimized composition for glass production
SiO_2	38,2 %	48,1 %
Al_2O_3	20,6	13,1
Fe_2O_3	2,4	19,2
FeO	27,1	19,2
CaO	2,6	10,6
MgO	6,7	5,9
$(K,Na)_2)$	0,04	2,3

4. Application of energy - saving technologies:

As a result of the first project carried out based on the classic double- firing technologies for the Jamaican Bauxite Institute in 1982, it transpired that without the elaboration of cold technological processes with low energy consumption the chances of application in countries poor in energy resources are low. At that time there was no request from Jamaica to continue with improved approach. In 1984, however, the Chinese Shandong Aluminium Works turned to UNIDO to help them to elaborate a low energy consumption programme for the economic utilization of their brown mud generated from alumina production based on series-combined Bayer technology. In implementation of the relevant contract concluded with UNIDO an energy sa ing single-firing technology was elaborated for the munfacturing of glazed floor and wall tiles, and a cold manufacturing technology for production of heat insulating foamed gas silicate blocks and bricks from the brown mud was developed. The single-firing manufacturing technology of producing glazed floor and wall tiles with a bulk density of 1,2-1,5 g/cm^3 is a new technique unique all over the world, resulting in a 40 % saving in energy as compared to the double or triple firing techniques usually required for the same purpose due to the requirements of mechanical strength of the tile material, its surface quality and esthetic appearance.

It is to be pointed out that this newly elaborated technology applied to the Chinese brown mud based floor and wall tile production results not only in the significant saving of energy, but also decrease of other wastage, better control of the process and smaller investment costs in comparison to the traditional clay mineral based production technology.

Later on, in the first half of 1986, this new techology was adapted within a new UNIDO project on red mud utilization for India with the same good results, described in the final report of the project, submitted through UNIDO in September this year.

5. The example of red mud of Korba Alumina Plant India

Economic calculations for the establishment of a proposed tile plant for 2 different capacities.

5.1. Unglazed single Fired Floor and Wall Tiles for red-mud technology for Industrial Use /Predesign estimate/ Annual capacity 150 000 sqm

A. Site, buildings, etc.

		RS	RS
1.	Land available by Messrs. BALCO		
2.	Raw materials storage area 500 sqm. Rs. 150/sqm.	75,000	
3.	Plant building, complete with lighting and utility connections 1000 sqm. Rs. 1500/sqm.	1,500,000	
4.	Subtotal		1,575,000

		RS	RS
B.	Machines and equipment		
5.	Plant machinery	9,375,000	
6.	Kiln	3,125,000	
7.	Subtotal		12,500,000
C.	Other pre-production capital costs		
8.	Engineering	60,000	
9.	Ceramic know-how	600,000	
10.	Technical assistance, supervision	60,000	
11.	Contingency, 10 % of A&B	1,407,500	
12.	Working capital, 20 % of annual sales / of Rs. 15,000,000/	3,000,000	
13.	Subtotal		5,127,500
14.	Total Capital Requirement		19,202,500

5.1.1 Unglazed tiles /predesign production cost estimate/

Product weight: 30 kg/sqm

product size: 200 x 200 x 15 mm

A.	Raw material		
1.	Red-mud - 2500 tons - Rs. 600/t	1,500,000	
2.	Lithomarge - 1500 tons - Rs. 20/t, ex works Korba	30,000	
3.	Arcosa-sand - 1000 tons - Rs. 20/t, ex works Korba	20,000	
4.	Subtotal		1,550,000
B.	Utilities		
5.	Light fuel oil - 720 tons - Rs. 3000/t	2,160,000	
6.	Power - 750,000 kWh - Rs. 0,5/kWh	375,000	
7.	Water - 4500 cu.m. - Rs. 1/cu.m. -	4,500	
8.	Subtotal		2,539,500

		RS	RS
C.	Labour required - 20 persons -		
	9. Rs. 900 a month/pers	216,000	216,000
D.	Miscellaneous		
	10. Maintenance and repair		
	2 % of building cost	31,500	
	5 % of equipment cost	468,750	
	2 % of kiln cost	62,500	
	11. Insurance and other cost		
	1 % of total investment	192,025	
	12. Depreciation		
	3 % of building cost	47,250	
	5 % of kiln cost	156,250	
	7 % of equipment cost	652,250	
	13. Overhead /administrative and selling/ 7 % of annual sales	1,050,000	
	14. Interest		
	12 % on 50 % of loan /Rs. 10,000,000/	1,200,000	
	15. Subtotal		3,864,525
	16. Total annual cost of operation		8,170,025

5.1.2 Unglazed tiles /Profitability/

1. Gross annual revenue from sales if 150,000 sqm. unglazed tiles for industrial use Rs. 100/sqm.	15,000,000	
2. annual cost of operation / see item 16 of 5.1.1. /	8,170,025	
3. Annual gross profit		6,829,975
4. Rate of return of capital outlay		

$$\text{/ excluding loan / RS. } \frac{6{,}829{,}975}{10{,}000{,}000} \times 100\ \% = 68{,}3\ \%$$

5. Pay back period	1,46 years

		RS	RS
Unglazed tiles / cash flow at Rs. 100/sqm. /			
1.	Gross profit /see item 3 of 5.1.2/		6,829,975
2.	Depreciation /see item 12 of 5.1.D./		859,720
3.	Annual repayment of loan principal of Rs. 10,000.000 in 7 years		1,050,000
4.	Net cash flow /1, 2. - 3./ in any production year		6,639,725

5.2. Glazed and decorated tiles for red-mud based technology /Predesign estimate/ Annual capacity 2,000,000 sqm, Single fired Floor and Wall Glazed Tiles

A.	Site, buildings, etc.		
1.	Land available by Messrs. BALCO		
2.	Raw materials storage area 1000 sqm. Rs. 150/sqm.	150,000	
3.	Plant building, complete with lighting and utility connections 10,000 sqm. Rs. 1500/sqm.	15,000,000	
			15,150,000
B.	Machines and equipment		
5.	Plant machinery	100,000,000	
6.	Kiln	18,750,000	
7.	Subtotal		118,750,000
C.	Other pre-production capital costs		
8.	Engineering	850,000	
9.	Ceramic know-how	2,500,000	
10.	Technical assistance, supervision	500,000	
11.	Contingency, 10 % of item A&B	13,390,000	
12.	Working capital, 20 % of annual sales /of Rs. 200,000,000/	40,000,000	
13.	Subtotal	57,240,000	57,240,000
TOTAL CAPITAL REQUIREMENT			191,140,000

5.3. Glazed and decorated Single Fired Floor and Wall Tiles /Predesign Production Cost Estimate/

Product weight: 20 kg/sqm

Product size: 200 x 200 x 7,5 mm
200 x 300 x 7,5 mm

		Rs	RS
A.	Raw material		
	1. Red-mud - 22,000 tons - Rs. 937,5 t	20,625,000	
	2. Lithomarg - 13,200 tons - Rs. 20/t	264,000	
	3. Arcosa-sand - 8,800 tons - Rs. 20/t	176,000	
	4. Subtotal		21,065,000
B.	Utilities		
	5. Glaze - 2750 tons - Rs. 13,450/t	36,987,500	
	6. Heating fuel Light fuel oil - 15,000 tons - Rs. 3000/t	45,000,000	
	7. Power - 7,595,000 kWh - Rs. 0,5/kWh	3,797,500	
	8. Water - 45,000 cu.m. - Rs. 1/cu.m.	45,000	
	9. Subtotal		85,830,000
C.	Labour required - 200 persons -		
	10. Rs. 900 a month/person	2,160,000	2,160,000
D.	Miscellaneous		
	11. 2 % of building cost	303,000	
	5 % of equipment cost	5,000,000	
	2 % of kiln cost	375,000	
	12. Insurance and other cost		
	1 % of total investment	1,911,000	

13.	depreciation		
	3 % of building cost	454,000	
	5 % of kiln cost	937,500	
	7 % of equipment cost	7,000,000	
14.	Overhead /administrative and		
	7 % of annual sales	14,000,000	
15.	Interest		
	12 % on 50 % of loan		
	/Rs. 100,000,000/	12,000,000	
16.	Subtotal		41,981,400
17.	TOTAL ANNUAL COST OF OPERATION		151,036 400

Glazed and decorated tiles /Profitability/

1.	Gross annual revenue from sales if 2,000,000 sqm. glazed and decorated single fired floor and wall tiles are sold at Rs. 100/sqm. /ex works/	200,000,000	
2.	Annual cost of operation /see item 17/	151,036,400	
3.	Annual gross profit		48,963,600
4.	Rate of return of capital outlay /excluding loan /		

$$\text{Rs.} \frac{48,963,600}{100,000,000} \times 100\ \% = \underline{49\ \%}$$

5.	Pay back period	2 years

Glazed and decorated tiles /cash flow at Rs. 100/sqm./

1.	Gross profit /see item 3 of 5.3.1/	48,963,600
2.	Depreciation /see item 13 of 5.3.D/	8,392,000

3. Annual repayment of loan principal of Rs. 1000,000, in 7 years 14,000,000
4. Net cash flow /1+2-3/in any production year 43,355,600

6. <u>The example of brown mud of the Shandong Aluminium Plant, People's Republic of China:</u>

Since details of the new compositions are at present under patenting procedures, only the case of brown mud of the red mud sintering branch of the series-complex process, applied at the Shandong Plant in China can be briefly described here.

The production of alumina in the Shandong Aluminium Work is carried out by the series-combined Bayer process and the recovery of the chemically bound caustic soda and alumina formed during the digestion of high silica bauxites is achieved by sintering of the bauxite residue with soda ash and limestone at 1.100 to 1.200 °C to generate calcium silicate and sodium aluminate.

This reaction is given by the following equation.

$$\underbrace{Na_2O.Al_2O_3.2SiO_2}_{\text{from bauxite residues}} + 2CaO + 2H_2O \qquad 2NaAlO_2 + \underbrace{2CaO.2SiO_2.2H_2O}_{\text{brown mud}}$$

The calcined product is ground and leached with dilute aluminate liquor to recover its sodium and alumina values.

The calcium silicate which residue is used partly to manufacture Portland cement and it is partly discharged to impoundment lakes.

The CaO content of brown mud is bound partly in $CaCO_3$ while the other part may be found primarily in dicalcium-silicate $(Ca2SiO)_4$ subordinately in sodalite (sodium-aluminium-silicate) and in genlenite $(2CaO.Al_2O_3.Fe_2O_3)$.

The Al_2O_3 is divided between the sodalite and the gehlenite approx. fifty-fifty per cent. The iron is bound to gehlenite, and other iron gels. On the derivatographic curves, the DTA indicates this state of iron by an elongated exotherm peak between 100-400 °C.

The exothermia beginning on 800 °C shows the decomposition of $CaCO_3$ and the polimorf transformation of dicalcium-silicate. Grain size distribution of the natural (dry) material is as follows:

a) bigger than 2 mm is 58 %
b) between 1-2 mm is 24 %
c) less than 1 mm is 18 %

The $CaCO_3$ content of the fractions above 2 mm, is between 30-36 % that of the fraction below 2 mm is between 25-30 %.

Grain size distribution of the soaked mud is as follows:

clay fraction	25 %
mud fraction	55 %
silt fraction	20 %

a) <u>Results of manufacturing of glazed floor and wall tiles on pilot-demonstration scale:</u>

The main oxyde components of the Shandong brown mud together with that of the floor - and wall tiles made from optimized mixture (40 % brown mud and 60 % of bauxite clay, sandstone and mining refuse) after firing is shown in Table 2.

Table 2: Composition of brown mud compared to that of the tile product

Components	Brown mud	Tile product
SiO_2	21,87	50,45 %
Al_2O_3	5,85	15,39
Fe_2O_3	7,14	5,61
CaO	45,90	20,89
MgO	1,61	0,84
Na_2O	1,84	1,14
K_2O	0,38	1,38
TiO_2	0,79	0,79

The technological sequence of floor and wall tile manufacturing is shown in comparison below:

Traditional technology	Technology elaborated for brown mud utilization
Raw material: different clay sorts, quartz	Raw material: brown mud
Additives: sand, dolomite, limestone flour, feldspar	Additives: bauxite clay, mining refuse, sandstone
Storage	Storage
Measuring	Measuring
Grinding	Grinding
Homogenization	Homogenization
Granulation	Granulation
Pressing	Pressing

Drying in tunnel dryer 12-36 hours	Rapid drying, 1 hour glazing
Bisquit firing 24-72 hours	Rapid firing 1,2 hours
Glazing	Sorting - packing
Glazed firing	Storage - delivery
Sorting - packing	
Storage - delivery	

The comparison of technical data of glazed wall tiles is shown as follows:

Technical data	Chinese white glazed tile	Brown mud tile
Size	150 x 150 x 5 mm	150 x 150 x 5 mm
Marketable product class I - II - III	90 %	90 %
I. Class product	45 %	75 %
Water absorption	22 %	15 %
Crushing strength	70 %	155 kp/cm^2

The comparison of economic efficiency of production is shown as follows:

	Glazed white tile of Zibo based on clay	Glazed tile based on brown mud
Distribution of production costs:		
- Raw materials	22,2 %	19,7 %
- Coal	12,9 %	4,4 %
- Electric energy	6,0 %	7,5 %
- Labour	7,0 %	0,4 %
- Loss of waste product	15,8 %	13,2 %
- Depreciation	22,7 %	35,3 %
- Cost of business management	13,4 %	19,5 %
Production cost	100,0 %	100,0 %
Production cost in percentage of valid price	72,4 %	49,9 %
Payback period	4,4 years	2,8 years

b. Results of manufacturing of bricks from brown mud and fly-ash on pilot/demonstration scale:

By pre-treatment of the coal at the plant power station before burning, based on a process, patented by the author, a fly-ash with acquired hydraulic bonding properties may be produced. A sample of this pre-treated fly-ash was tested as the second main component of a mixture - see initial composition data below.

Table 3: Composition of brown mud and fly-ash used for the tests

Components	Brown mud	Fly-ash*
SiO_2	21,87	43,43
Al_2O_3	5,85	22,22
Fe_2O_3	7,14	17,51
CaO	45,90	1,25
MgO	1.61	0,20
Na_2O	1,84	0,24
K_2O	0,38	1,52
TiO_2	0,79	0,86

* L.O.I. - 8,35 %; C - org - 0,42 %

The ratio of 60 % brown mud and 40 % pre-treated fly-ash was used with the application of a new technological scheme as follows:

Traditional technology	Technology elaborated for China
Raw materials: good quality soil for agricultural products (rice), clay	Brown mud
Additive: sand if required	treated fly-ash, (cement)
Clay mining	Drying of brown mud by hot flue gas from rotary kiln
Storage	Storage

Preparation of the material (mixing, homogenization)	Preparation of the material (mixing, addition of water, homogenization)
Shaping (by hand or by machine)	Shaping (by hand or by machine)
Drying in open air pile	Conditionning in open air pile (sprayed fròm the third day by water)
Firing in Hoffmann-kiln (10-90 days)	Delivery of the bricks from the 5th day
Discharging the bricks from the kiln intermittently after cooling	
Delivery on the 30th-120th day after shaping	

The comparison of technical data of the bricks is shown as follows:

Technical data	Traditional Chinese clay bricks	Brown mud brick
Size	240x115x53 mm	240x115x53 mm
Density	1,7 g/cm^3	1,4 g/cm^3
Water absorptivity	14-16 %	14 %
Compressive strength kg/cm^2	100	150
Breaking strength kg/cm^2	22	20

Comparison of economic efficiency of production
(Data related to a production unit of 10 million pcs/year)

	Traditionally manufactured brick in China	Brown red mud brick producted by cold technology
Brick size	53x115x240 mm	53x115x240 mm
Weight of one brick	2,3-2,68 kg complying with Chinese standard	2 kg complying with Chinese standard

Distribution of production cost:

- Raw material	20 %	30,13 %
- Coal	17,8	-
- Electric energy	12,5	6,4
- Labour cost	17,9	1,96
- Depreciation charge of equipment	9,4	50,36
- Water	-	0,5
- Maintenance cost of equipment	11,2 %	7
- Business management and other	11,2	3,6
- Production cost	100,0	100,0

Production cost in the percentage of valid price	80	59,4
Payback period of the investment	10,4 year	2,0 years

7. Conclusions:

The processing of bauxite to alumina leads to the accumulation of solid residues in large quantities. The handling and disposal of this material is expensive and poses continuous environmental problems and difficulties. Therefore, many countries are looking for ways and means of decreasing this environmental hazard through profitable utilization of these residues on a large scale. Unfortunately, the progress made towards identification of technically and econoomically viable technologies in processing red mud on a sufficiently large industrial scale has been extremely slow until now.

A new process utilizing red mud has been developed by the author with the production of floor and roof tiles, bricks and light construction blocks containing 40 - 90 % of red mud and other common additives usually locally available. Recongnizing this industrial opportunity, some developing countries have requested through UNIDO to study their specific cases and projects have been implemented for Jamica, India and China. These projects prepared techno-economic assessments of industrial processing of red mud from alumina production and included laboratory and pilot scale elaborations and testings of mixtures from red mud and other wastes with local additives.

In the case of Jamaica the tests yielded successful technical results and it is now proposed to apply these results for additional elaboration of energy saving technological variants. In the case of China, the study of bauxite residues from the Shandong alumina plant showed that the brown mud available there can also economically be processed into value added building materials. The report recommended the establishment of a plant that could produce 100 million bricks and 2 million m^2 tiles per year.

In case of India, the puting up of industrial processing for sludges from the steel industry is in progress and based on the study results industrial units, based on cold techology are proposed to be set up for red mud and garnet sand residues.