

The full report for 4th Asean Bauxite & Alumina Conference
Subject: Showcase of alumina refining Projects

Vietnam: Highland bauxite Projects and initial economic effects

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Tan Rai (Lam Dong) and Nhan Co (Dac Nong) bauxite & alumina Projects and Dac Nong aluminium electrolyte Project are Vietnam's National main point large works aiming at target to transfer the economic structure after fastly increasing direction of industrial proportion in GDP, taking part in giving Vietnam to become the country of model industry at 2020. This is the first important Projects on deep preparation of bauxite ores with complex technology, carried out in Highland, the area of difficult special economic conditions. However by strengthen of engineers and workers of the Vietnam Industrial Group of Coal - Minerals (VINACOMIN) after four developing years (2011 – 2014), these projects have obtained initial economic effects.

I. The great potential of Highland bauxite

Bauxite resource is very abundant and widely distributive in many locations of Vietnam, especially in wide Highland. This is favourable condition for exploitation and development of alumina industry in large scale. After the project of bauxite exploitation and aluminium production of Highland area during 2010 – 2020, four plants will be built. Other two aluminium production plants of smaller scale in Northeast Bac Bo region also will be built after that. This important industrial sector requires large investment and exploitation of mineral resource is connected with many elements of economy and environment, hence Vietnam Government welcomes and creates every favour conditions to the domestic businesses and foreign investors for development of aluminium industry, aiming at Vietnam to become the leading country in the Southeast Asian region and the world in 21 century.

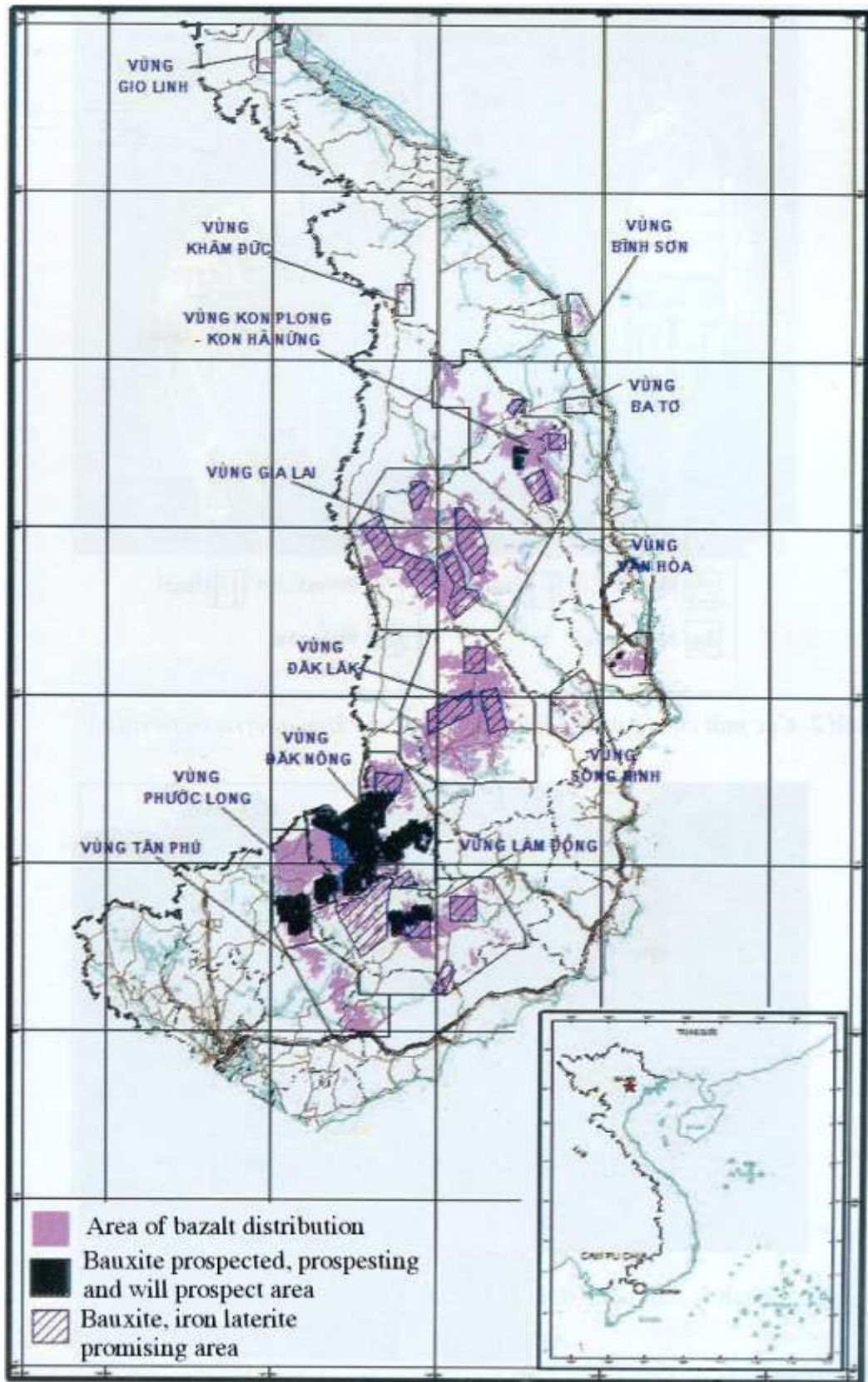
In North Vietnam, bauxite was found in provinces of Lang Son, Cao Bang, Ha Giang, Lai Chau, Dien Bien, Hai Duong and Nghe An. But the concentration zone of bauxite mines is only in Lang Son, Cao Bang and Ha Giang provinces with small deposits and occurrences. The bauxite ores appear, either deluvial placer ore or primary one in limestone with total reserve attaining over 306 million tons.

In South Vietnam, in weathering basalt rocks, very large reserve of bauxite ores, able to industrial exploitation discovered, especially in Dac Nong and Lam Dong provinces in South Highland.

Total reserve of bauxite ore in South Vietnam explored and estimated to 2006 is 5, 616. 394 m tonnes, in which Dac Nong - 4.237.6 m tonnes, Lam Dong - 763.4 m tonnes, Gia Lai - Kon Tum - 367.39 m tonnes; Quang Nam and Quang Ngai - 0.694 m tonnes; Phu Yen and Dac Lac – 30.23 m tonnes and Binh Phuoc - Dong Nai – 216.70 m. tonnes.

In Dac Nong deposit area, there are 12 deposits, distributing on area of 638.0 km² of total reserve as 4,236.6 m. tonnes (occupying 75 % total reserve), of which clean ores (+1mm) have reserve of 1,869.78 m. tonnes with average content Al₂O₃ 48.3%, SiO₂ 2.6, Fe₂O₃ 18.93%, MSi 18,5% and a recovery of 44.6%.

Fig.1. Bauxite prospected area in Dac Nong and Lam Dong (Highland)



In Lam Dong deposit area, there is 2 deposits, distributing on area of 287.0 km², with total reserve of 763.4 m. tonnes, of which clean ores (+1mm) have reserve of 313.05 m. tonnes (Table 1).

The Tan Rai (Lam Dong) and Nhan Co (Dac Nong) deposits were detailed prospected for development of Tan Rai and Nhan Co bauxite and alumina Projects.

Bauxite quality and reserve in Dac Nong and Lam Dong provinces

Table 1

N ^o	Area/ Deposit name	Area (km ²)	Commercial ore quality			Reserve (m. tonnes)	
			Al ₂ O ₃	SiO ₂	MSi	Crude ore	Clean ore
I	Dac Nong						
1	Nhan Co	49.9	49.47	2.34	23.1	359.3	164.6
2	“1 th – May”	34.7	48.30	3.45	14.0	204.7	100.98
3	Gia Nghia	45.0	47.99	2.58	18.6	311.6	155.6
4	North Gia Nghia	44.6	48.74	2.20	21.2	401.1	242.3
5	Trung Duc	56.3	48.74	2.20	22.2	356.9	68.3
6	Quang Son	40.0	-	-	-	262.5	164.6
7	Dac Song	50.0	-	-	-	372.5	188.6
8	Bu Bong	93.5	-	-	-	530.7	196.9
9	Dac Rung	54.6	-	-	-	411.1	162.8
10	Dao Nghia	90.9	-	-	-	640.8	298.6
11	Dac Tinh	19.1	-	-	-	82.2	27.6
12	Dac Ton	59.4	-	-	-	204.2	98.9
		Σ638.0				Σ4.237.6	Σ1.869.78
V	Lam Dong						
1	Tan Rai, of that	220	44.69	2.61	17.1	385.4	176.59
	- West zone	42	-	-	-	148.76	59.83
2	Bao Loc, of those	67.0	44.7	2.6	17	378.0	136.46
	Thang Loi hill zone	2.5	-	-	20	7.04	3.09
	Nam Phuong hill	0.5	-	-	-	2.90	0.80
		Σ287.0				Σ763.4	Σ 313.05

The deposits of bauxite in Dac Nong and Lam Dong provinces have median and large reserve scale, one another near distance and one another connected into each deposit group, favourable to exploitation and production of alumina in the large scale.

Covering soil layer on orebodies is thin (0.5 – 1.0 m), plateau terrain is rather flat, favourable for mining. Alumina bearing mineral in bauxite ores is loose gibbsite (Al₂O₃·3H₂O); Alumina content in concentrate is from 44.4 to 53.2 %; silica only from 1.6 to 5.1%, suitable with production technology by Bayer method in lower temperature, little expense of energy, product cost is low, then it was estimated as one of the best bauxite ore kinds in the World.

II. Tan Rai Alumina production project

The Tan Rai alumina Plant in Lam Dong province with design capacity of 650 000 tpa, to manufacture of chemical alumina. Tan Rai deposit, where has supplying material to the plant, lies between two districts of Bao Loc and Di Linh, Lam Dong province.. The weathering laterite crust of Pleistocene age is thick from 20 to 26 m, In upper part are bauxite beds of industrial value of 1 – 12 m thickness. The bauxite ore beds are formed in highness 800 – 1000m altitude. Mineral composition consists of gibbsite (59.2%), goetite (17.4%), kaolinite (8.8%) and ilmenite (3%). It was determined 385.4 m. tonnes reserve in C₁ + C₂ categories (Indicated and Inferred) with average recovery of concentrate as 44.4%.. Reserve of bauxite concentrate is 176.6 m tonnes with average content (%): Al₂O₃ 44.69, SiO₂ 2.61, Fe₂O₃ 23.35, TiO₂ 3.25 , LOI 24.30 and MSi 17.1 Table 1), in which the West zone being mined to have 42 km² area with reserve of 148.76 m. tonnes, and concentrate as 59.83 m tonnes, It is mined an open cast, thin covering bed (0.5 – 1.0 m), easy to exploit. Each 2.2 to 2.5 tonnes of crude ores will gather 1 tonne of concentrate of alumina content from 45% up wards. Each about 2 tonnes of concentrate or more a little will gather 1 tonne of alumina with Al₂O₃ is no low than 98.6%.

In March 2011, at the Tan Rai deposit (Bao Loc district, Lam Dong prov.), the Vietnam Industrial Group of Coal - Minerals (VINACOMIN) organized mining and conducting in operation of processing Plant with design capacity of 4 m tpa for ore supplying to alumina plant at the Tan Rai bauxite - aluminium Combination. The Tan Rai alumina Plant has fulfilling the final works and go into operation in October 2013.(Fig 4)

Fig 2, Panorama of Tan Rai (Lam Dong) alumina production plant



1. Productin technology: At present, in the World are about 100 plants in 27 countries manufactured alumina after Bayer method. The project of Tan Rai bauxite and alumina Combination of Vietnam is also application of this technotology.

Bayer technology was invented by Karl Bayer in 1887, according to that, firstly bauxite is grinded finely and mixed with the chemicals as sodium hydroxite, soda and lime, and gived in separating equipment of very large presure sustaining and hot water. After that, chemicals be added (lime to regenerating the soda), and hydrated alumina is crystallized from solusion after seed creation with hydrate crystals. These crystals are washed cleanly and burning at very high temperature for discharged finishing water, giving to time obtained white powder form. It is alumina or aluminium oxid.

The norm for evaluation of bauxite quality after Bayer method is mainly based on consuming measure of bauxite ore and alkaline (Na_2O) for manufacture of one alumina tonne:

1. Good grade consumes 2.2 tonne of bauxite ore and $< 40\%$ alkaline
2. Mean grade consumes from 2.2 to 2.9 ore tonnes and from 40 to 80% alkaline,
3. Poor grade consumes > 2.9 tonne of bauxite ore and $> 80\%$ alkaline.

Research results shown the lateritic bauxite in Highland is chiefly trihydrate and gibbsite, easy to dissolve and separate in temperature of 105°C with solution concentration of 210 gr/l Na_2O or 145°C with solution concentration of 160 g/l Na_2O ; separating time is 2.5 – 3 hour and may reach effect to 90%. Consuming measure is from 2.15 to 2.30 ore tonnes for manufacturing one tonne of alumina. Thus, bauxite ore quality of Tan Rai belongs to rather good grade.

In production process after Bayer technology, it had carried out steps:

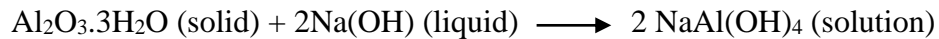
- *Ore crushing* : First of all, bauxite concentrate after processing is handed in crushing system. In that, bauxite is crushed wet in crushing mill, after ore mixed with alkaline solution (NaOH), supplying from intermediary tub after defined solid/fluid ratio, usualy about 50/50. Bauxite ore of 1 – 20 mm.grain size is crushed to fineness of 500μ grain size (Fig.3)

Fig.3, Bauxite concentrate gave in preparation workshop

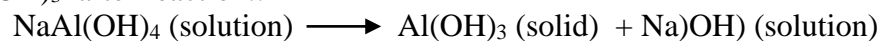


- *Silic rejected*: suspension after crushing be previously rejected the silic in 95 – 100°C during 10 hours period, for transferring of active silic to hydrated sodium aluminosilicate of general formula $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ in solid form.

- *Dissolve – separating* : giving the mixture in dissolve - separating equipment together with condensed rotated solution, mixed after suitable ratio. In here, it happened soluble reaction of alumina in bauxite ore, transferring alumina from solid phase became in alkaline solution under pressure of about 5 at and low temperature (140 – 145°C) after reaction:



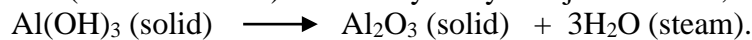
- *Settle – filtering*: for rejecting the impurities, $\text{NaAl}(\text{OH})_4$ solution is moved to filtering equipment, using usually membrane kind. After filtering, the solution of solid matter content below 3 mg/l will be cooled, for transferring of sodium aluminosilicate solution to pass a supersaturated state and gave in seed forming equipment . In here, sodium aluminosilicate solution will be differentiated oneself and formation of alumin hydroxite $\text{Al}(\text{OH})_3$ after reaction::



Some aid - settle matters used, helping to prompter settling process, because the Tan Rai bauxite ore belonging to difficult setting kind..

- *Crystallized*: after passing seed formation stage, the seed containing sodium aluminosilicate solution will flow pass crystallized equipment. Under action of additional seed , the alumin hydroxite crystals will be crystallized to requiring size, then handing pass separating zone. Alumina crystallized technology application in sand form is suitable form compared with aluminium electrolysis technology at present. .

- *Heating* : the used equipment to heating alumin hydroxite ($\text{Al}(\text{OH})_3$) into alumina at Tan Rai plant is the heating equipment in boiling bed kiln In here, with high temperature (1100 – 1200°C) alumin hydroxyte rejected water, forming alumina.



Production process has realized strictly the demands of technology and combined closely, therefore it has arained the forwarded tagets and requirements.(Fig.4)

Fig.4. Preparation plant of alumina at Tan Rai bauxite deposit



Fig. 5. First product haul of Tan Rai alumina plant released from factory



Alumina product is given in storage, packaging and released from the factory.

First product lot exporting: In testing production process, the plant has produced over 110,000 tonnes alumina of 98.6% pureness, guaranteeing to exporting standard. Domestic and international consumers shown to satisfied to product of Tan Rai alumina plant. This is really glad news to workers and engineers of VINACOMIN, marked a turning – point in young aluminium industry of Vietnam.

Product has been sold to four dominic businesses and exported to four consumers in Switzerland, Singapore, South Korea and China and signed the contracts selling alumina with 11 customers. Calculating to August, 2014, the alumina product of Tan Rai plant has exported to reach 411, 528 tons.

In commercial operation stage, from October 1th, 2013 to last July, 2014, Tan Rai alumine has produced 351,578 tons alumina, 533,480 tons of aluminium hydroxit. Anticipating in 2014, the plant will reach 70 – 80% design capacity (650,000 tpa).

As though, it is possible to confirm that, problem of product consume is completely not worthy of minding as a former public opinion has once spoke up.

Exporting alumina product is transposed after two lines: Line 1 from provincial road 726 (Lam Dong) and after National highway 20 to Da Lat City, after National highway 27 down Phan Rang – Thap Chap City (Ninh Thuan province) and then after National highway 1 running on North site to Cam Ranh port (Khanh Hoa province), with distance of 300 - 350 km, and Line 2., going from the provincial road 725 (Lam Dong) to National highway 20, after provincial road 769 (Dong Nai province) and after National highway 51 to Go Dau port (Dong Nai) with distance of 400 – 450 km.

One subject will be focussed on discussion at 4th Asian Bauxite and Alumina Conference that: How much will the Indonesia export ban help/detriment Atlantic export vs Pacific export. After my opinion, that fact will non effect much to countries of alumina and aluminium exporting requirement, against can stimulate to activity of some

countries in Asia and Pacific region of large bauxite potential, in which is Vietnam, pushing up production and exporting of alumina and aluminium.

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2. Problem solution of red mud treatment and environment protect: Process of bauxite exploitation and ore processing will discard in environment of red mud and oxalate mud from final washing stage. Especially, discarded red mud from processing process, out impurities such as iron, silic, titanium and calcium oxides, it still contains compounds of chemical link with alkaline (silic – aluminium – natrium hydroxides), having high pH (12 – 13). Each tonne of manufactured alumina (Al_2O_3) can discard the environment from 0.4 to 2 tonnes of red mud. Therefore, the red mud treatment and environment protect is problem especially concerned by public opinion when development of Highland bauxite projects. .

Red mud treatment: In the Tan Rai Project developing progress, 6 filtering sewers system was built. . The impurities and chemicals recovery of bauxite processing process and alumine production is realized in dry form. Discard sodium hydroxide is recovered, surving to production. Technology has been applicating in Tan Rai alumina Plant at present and of Nhan Co alumina Project after that also will be red mud recovery in dry form being applicating in about 70% of alumina production Plants in the World.. Therefore, it is affirm that dam breaking threat of large red mud containing tank as the dam broke in the Ajka (Hungari) red mud tank in October 4, 2011 will can not happen.

Guarantee to supply water for production:: Process of bauxite exploitation and alumina production consumes a amount of very large water, especially in ore washing stage and alumina separation. It is considered that one plant of 650, 000 tpa alumina capacity need uses about $10 \cdot 10^6$ water m^3 /year for ore processing and $4.5 \cdot 10^6$ water m^3 /year for alumina production. Total water amount needing to Project of Tan Rai bauxite and alumina in Lam Dong is about $20 \cdot 10^6$ water m^3 /year. The Highland is the region of no-much rain water amount. and only occurs in rain season (from May to October). Therefore, guarantee to supply water for production is problem concerned very much by publish opinion.

The water source serving for ore processing and alumina proction in Tan Rai plant fully met by large lake of 20 m^3 capacity, also has been built completely. .

In dry seasons, out serving for alumina production, water from this lake still contributed part to overcome in droughth situation in agricultural production, which is very cheerful for local people.

Exploitation in combination with land return: By geological character of Highland region in general, and in Tan Rai bauxite deposit area in particular, the cover bed on bauxite orebodies has very little thickness, usually from 0.5 to 1.0.m, that is why when mined, the quarry area enlarges very fastly, restricting considerably the forest land area, attacking to envirenment. For diminishing bad impact to environment, in Tan Rai bauxite and alumina Project, mined ore to wherever, the land returning be executed to there. Anticipating the land return will fulfilled after three mined years.

So, it is perfectly possible affirm that the Tan Rai bauxite and alumina Project, one of two main point Projects of Vietnam' mineral exploitation industrial sector hosted by VINACOMIN, has completed as outstanding all planed targets and tasks after about 30 months to executing. Even in 2013, the Tan Rai alumina Plant can be producted about 200,000 tonnes and will attain designing capacity of 650,000 tpa in 2015 or 2016.

III. Nhan Co alumina Project

Project of Nhan Co Bauxite and Alumina is developed in Dac Nong province, the area is the largest bauxite reserve in Highland, Vietnam.

In Dac Nong province were found and estimated 12 deposits of total reserve as 4,236.6 m. tonnes (occupying 75% total reserve of Highland), of which are large deposits as Nhan Co, Dao Nghia, Gia Nghia, Quang Son and 1st May (Table 1). Therefore, Dac Nong is worthy chosen to become centre of Vietnam' aluminium industrial development in future. Nhan Co bauxite and alumina combination is the bigging project for many large projects will be constructed in following years, as:

- The N^o1 Dac Nong aluminium plant with capacity of 1,900,000 tpa..
- The N^o2 Dac Nong aluminium plant, with capacity of 1,500, 000 tpa. Now, the detailed prospecting of Gia Nghia deposit has been carrying out for ore supply to plant.

The Nhan Co bauxite deposit is of distributional area 49.9 km², with reserve 359.3 m. tonnes, of those clear ore as 164.6 m tonnes.. Here is also deposit of the best ore quality in Dac Nong province, with content Al₂O₃ 49.47 %, SiO₂ 2.34% and Msi 23.1.

VINACOMIN has corrected the design to Nhan Co project, raised capacity from 300 000 tpa alumina after beginning design (2006) to 650 000 tpa (2008). The Project has starting building in early 2012.

Now all activities on building site have been realized after right rate. The contract packs of alumina plant have carried out in 72/73 articles, in which all equipments have been transported to project base. The contractors have executing assemblage of equipments, in which completed work amount reaching over 80 - 90%. (Fig.6 to 9).

The Nhan Co alumina plant can be completed and going operation at 2015.

IV. Dac Nong aluminium electrolyte Project

In last september 4th, 2014, Vietnam has began to work the Project of the first aluminium electrolyte in Nhan Co industry Zone, Dac Nong province. Project invested by Tran Hong Quan metallurgy limited Company, with capacity of 300,000 tpa aluminium, orienting to increase a capacity up 450,000 tpa, with total capital to invest up \$575m.

It is project using material supplied by the Nhan Co (Dac Nong) and Tan Rai alumina (Lam Dong) plants of VNACOMIN. Anticipating, the Dac Nong aluminium electrolyte plant will begin giving its product from last 2016, completing to raise a capacity in last 2019. When, receipts wishing to reach \$1.35 billion/year. The project is also important solution raising the bauxite resource value, consuming stable alumina, lessening for transport of alumina material by land from Highland to sea ports.

The project of Dac Nong aluminium electrolyte has been received many priorities of Government, such as tax of bussiness income, importing tax for importing merchandises for forming fixed property, tax of importing merchandises as raw material, material of semi - finished product, which not produced yet in inside, serving for production of Project. In addition, the Project still is gave hiring land and is exempt the land tax according to decision of law in force applicated to the projects belonging to sectors of particular priority to investment.

V. Investing to development of aluminium industry, a prior sector

∴ Orient of aluminium industry development in coming 10 – 15 years is put forward Vietnam to become one of leading aluminium production countries in the region and in the World, consequence, Vietnam Government will create every favour conditions and has much prior polycies to domestic businesses and foreign investors to invest in bauxite exploitation and aluminium production. Out two large projects hosted by VINACOMIN as Tan Rai and Nhan Co, many other projects have been prepared:

- The N°1 Dac Nong aluminium project with capacity of 1,900,000 tpa..
- The N°2 Dac Nong aluminium project with capacity of 1,500,000 tpa.
- The Kon Ha Nung aluminium project of 1,000,000 – 1,500,000 tpa, using bauxite ores of two mines of Kon Ha Nung and Mang Den in Gia Lai – Kon Tum provinces.
- Construction of two aluminium plants in Cao Bang and Lang Son provinces (Northeast Bac Bo), each plant having capacity of 500,000 aluminium tpa.

Fig. 6. Assemble of heating kilnes



Fig 7. Crystallization tubs were assembled



Fig 8. Nhan Co alumina plant building site, October 2013



Fig 9. Nhan Co alumina Plant site



Database for these projects were prepared and ready to supply for investors as reserve scale of deposits, ore quality and enrichment ability, mining conditions and transport, the econo – social situation of area etc.

Now, it is looking into ability to 2020, the bauxite deposits in Highland must guarantee to exploitate from 54 to 75 m tonnes of crude ores aiming a recovery of 21.5 to

30 m tonnes concentrate supplying to Plants for production of 7.2 to 8.3 tonnes alumina.

For encouraging of investors, Vietnam Government has promulgated many prior policies such as be exempt tax, lessen tax in a space of time, be gave hired by State the land and be exempt to land tax after decision of Law in operation applicated for the projects belonging to fields, which are special priorities for investing.

Mineral Law 2010 had some amended points after direction to create more favourable conditions for foreign investors to development of mining industry, in which it is worthy of most attention to be **“Auction of the right to exploit mineral resources”**, after that, the busineses of able finance and advanced technology is easy to gain the large Projects of prospecting, exploitation and processing of mineral resources, in which are projects if bauxite mined and aluminium production.in Highland, Vietnam.

Reference

[1] Dinh Van Dien et al., 1979. Mineral resources of North Vietnam, Volume 4. Non – ferrous, precious, rare metals. . General Department of Geology. Ha Noi.

[2] Ho Sy Giao, 2011. Highland bauxite and environment problems being concerning by public opinions, Mining Industry Journal, N^o2/ 2011, p. 8 – 11.

[3] Le Duong Quang, Nguyen Manh Quan, 2004. Vietnam’ bauxite mineral potential and orient for investment business. The 16th National workshop on Mining science and technology, Proceedings, Vietnam Mining Science and Technology, Ha Noi.

[4] Le Van Trao, Pham Van Man, 1995. Bauxites of Vietnam. Geology, Mineral resources and Petroleum of Vietnam. Volume 2 – Minerals. Proceedings of the third geological Conference of Vietnam on the occasion of the 50th anniversary of the geological Branch of Vietnam, p. 85 – 97. Geological Survey of Vietnam., Ha No

[5] Nguyen Duc Hao et al., 2006. Research of scientific and practical base for establishment of reserve and resource ranking norm of Vietnam bauxite. In record of science – technology researching projects of Natural resources and Environment Branch in 2002 – 2006 stage. Ministry of Natural resources and Environment, Ha Noi.

[6] Nguyen Xuan Ba, 2006. Situation of the bauxite exploitation and aluminium production in the World, and development orient for aluminium industry in Vietnam. The XVIIth National Conference of Mining Science – Technology, Proceedings of scientific reports, p. 50 – 55. Vietnam Mining Association, Ha Noi.

[7] Duong Ngoc Tinh et al., 2010. Potential of bauxite and lateritic iron in basalt weathering crust in South Vietnam. Journal of Geology, Series A, N^o 320, p. 355 – 366. General Department of Geology and Minerals, Ha Noi.

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