

## Bauxite developments in Vietnam : Opportunities and Challenges

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### Abstract

Bauxite is the principal raw material to produce alumina. Bauxite mining industry has grown gradually due to the rising demand for alumina. U.S Geological Surveys (USGS 2018) estimates the world's reserves of bauxite roughly 55-75 billion tonnes. Vietnam holds up to 3.7 billion tonnes, the third after Guinea and Australia. Most of bauxite reserves are located in Tay Nguyen (Central Highlands), and have only been minimally mined to date. The approved master plan in 2007 of the Government of Vietnam licenses bauxite mining and alumina production projects in Central Highlands through six projects until 2025. These projects constitute many potentially enormous economic, social and environmental impacts.

**Key words** : Bauxite, residual, Central Highlands, environment

### 1. Introduction

Bauxite is the main raw material used in the aluminum manufacturing, and is one of the most economically minerals. According to United States Geological Survey (USGS), world's bauxite resources are estimated approximately 55 to 75 billion tonnes. Bauxite reserve in Vietnam is estimated to be 3.7 billion tonnes (Mineral Commodity Summaries 2018, 2018). It is account for approximately 12.3% of the world's reserve, less than Guinea (7.4 billion tonnes) and Australia (6.0 billion tonnes).

Hoang H (2009) demonstrated that 90% of Vietnam's bauxite reserve is distributed in the Central Highlands. In 2007, Vietnamese government has declared the Master plan (decision No. 167/2007/QD-TTg, 2007) to start its bauxite mining alumina production projects. The exploration, and processing of bauxite is a

strategic policy (announcement No. 245-TB/TW, 2009) and priority industry (decision No. 55/2007/QD-TTg, 2007) aimed at developing regional as well as national economy. The Central Highlands was a strategic region in the Vietnam's history and is also a strategic region in developing economy and defending (Rambo A.T, 1995). Since the extraction bauxite here has been posing the great challenge of balancing between economic development and negative impacts on regional and national wide. A large-scale bauxite mining holds many risks on society, environment, culture and national security (Giap V.N, 2009). Therefore, mining bauxite should be fully examined to minimum negative impacts.

An overview of bauxite mining practices in Vietnam is showed in this paper, and a brief discussion of social and environmental challenges is also provided. It could illustrate the basis of future challenges on bauxite development in Vietnam.

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## 2. Bauxite deposits in Vietnam

### 2.1 Background information

Vietnam, with a total landmass of 331,210 km<sup>2</sup>, locates on the east of Indochina peninsula. The country has S-shaped, with the length of 1,650 kilometers, the narrowest wide is about 50 kilometers, and of 3,260 kilometers coastline along the East Sea. Vietnam is located in both a tropical and a temperate zone, and has a high rate of rainfall, and high humidity. The annual average temperatures range from 22°C to 27°C (<http://weatheronline.co.uk>), rainfall normally between 1,500 and 2,500 millimeters per year, and relative humidity of 84 % on average throughout the year.

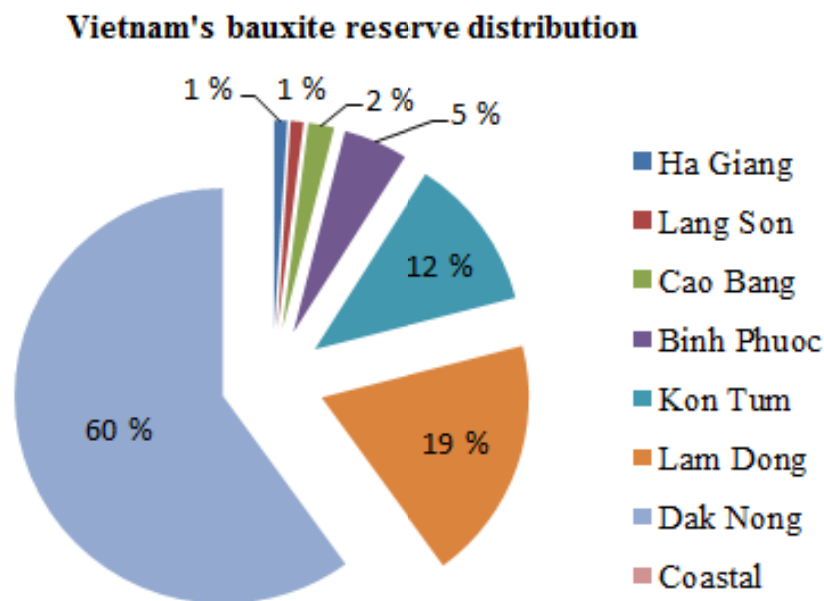
Imrich Kušnir (2010) indicated that Vietnam's mineral resources are rich in term of quality and quantity. Vietnam owns some of the world's top resources, including bauxites, and large reserves of fuel and nonfuel minerals (Ministry of Industry, 2002; Khoi N.N, 2014). Vietnam's bauxite reserves are mainly located in Dak Nong, Lam Dong, and Dak Lak provinces (figure 1).

Central Highlands has been a strategic region with a particularly important position in developing and defending of Vietnam, sharing the border with Lao and Cambodia. It is a highland terrain area covering 54,600 km<sup>2</sup> of land surface including 5 provinces

Kon Tum, Gia Lai, Dak Lak, Dak Nong, and Lam Dong (North-to-South). When the Master Plan was approved and signed by Vietnamese government, with the strategic investors is Chinese government, widespread debates against mining bauxite projects are overwhelming because of the potentially risks on society, environment, culture, and particularly national security.

### 2.2 Resources and distribution

According to the geological surveys (Liem N.V, 1966; Trung T.T, 1972, 1976, 1977; Tinh D.N et al, 2010), bauxite resource is very abundant and widely distributive in many locations of Vietnam, especially in Central Highlands (Xinh L.T, 1988; Lazarus K.M, 2009) (figure 1). This facilitates the exploitation and development of aluminium industry in large scale (Phuong T.K, 2015). As classification of bauxite based on genetic principles (Ida Valeton, 1972), Vietnam's bauxite is classified in two types: sedimentary (karstified limestones) (Trung T.T, 1976; Iacusep V et al, 1978), and lateritic bauxite (weathered basalts) (Iacusep V, 1979; Nhuan M.T, 1983). While, sedimentary bauxites are distributed mainly in the North (Hung L, 1972; Kušnir I, 2000), with the main minerals being monounsaturated (boehmite, diaspor), the lateritic deposits are developed mainly in the South with the main mineral component being hydrate 3 (gibbsite) (Vinachem, 2006).



**Figure 1.** Distribution of bauxite reserves in Vietnam (Lazarus K.M, 2009).

In North Vietnam, bauxite was concentrated in Lang Son (0.02 Mt), Cao Bang (77 Mt) and Ha Giang (49 Mt). (Vinachem, 2006). In South Vietnam, very large reserve of bauxite ores was identified on weathering basalt rocks, especially Dak Nong and Lam Dong provinces in Central Highlands.

### 3. Bauxite mining and residual practices

Vietnamese government has recognized mining industry as one of the leading contributor to the national economy. It is responsible for approximately 7.47 % of the country's gross domestic product in 2017 (General statistic office of Vietnam, 2017), the fourth largest sector after manufacturing, agriculture, and wholesale & retail trade. Vietnamese Prime Minister Nguyen Tan Dung said bauxite reserves in Vietnam may total 11 billion metric tonnes (Oanh K.H et al, 2010). The Mineral Commodity summaries 2018 ranked Vietnam as the third largest holder with 3.7 billion tonnes (USGS, 2018). This does hold great prospects for building an alumina-refining industry.

Initially, before 1945, Vietnam's bauxite was investigated and exploited by French in the north. Presently, Vietnam has three bauxite mining projects are operating (Huan T.M, Loi V.D, 2017) including Tan

Binh Chemical Plant (Ho Chi Minh City), Tan Rai Plant (Lam Dong province), and Nhan Co Plant (Dak Nong province). Table 1 demonstrates the detail description for the investments of Tan Rai and Nhan Co projects (Hoang H. 2009), two most important projects of Decision 167. After two projects Tan Rai and Nhan Co, four following projects of bauxite mining and aluminium production in Central Highlands will be founded (Lazarus K.M, 2009) (table 2). Other two aluminium production projects of smaller scale in Northeast Bac Bo region also will be founded after that (Phuong T.K, 2014).

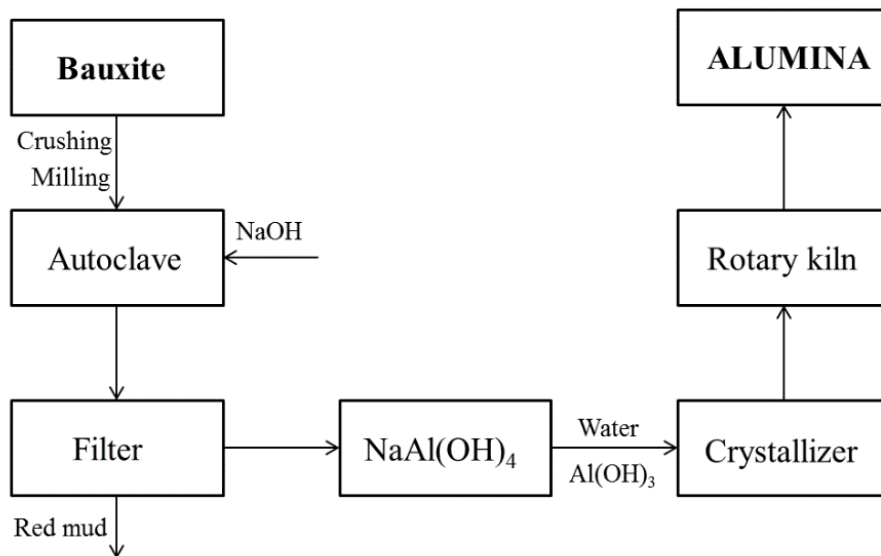
The projects of alumina production named Tan Rai and Nhan Co have been adopting production process after Bayer technology (Phuong T.K, 2015). Figure 2 presents a simplified flow diagram of Bayer technology (Szépvölgyi J, 2011). In Bayer process, an enormous quantity of "toxic waste" known as red mud will be generated. Discarded red mud contains compounds of chemical link with alkaline, having high pH (9.2-12.8) (Gräfe M et al, 2011) due to digestion at elevated temperature and pressure in Bayer's process, and remains impurities such as iron, silicon, titanium and calcium oxides. Each ton of manufactured alumina ( $Al_2O_3$ ) can discard to environment 0.4- 2 tonnes of red mud (Abhilash S.S, 2014).

**Table 1.** The investment items of Tan Rai and Nhan Co projects.

| Items                                | Unit                         | Tan Rai | Nhan Co | Note                                                                           |
|--------------------------------------|------------------------------|---------|---------|--------------------------------------------------------------------------------|
| Total investment                     | billion USD                  | 628     | 697     | Annual interest and principal payment rate of 7%                               |
| Capacity of mining                   | million tonnes               | 1.2     | 1.2     | Lam Dong province and Dak Nong province                                        |
| Alumina output                       | million tonnes               | 0.6     | 0.6     | Doubled in phase II (2016-2025)                                                |
| Water use                            | Million m <sup>3</sup> /year | 1.5-2   | 1.5-2   | Construct Cai Bang and Dak R'Tih hydropower plants to supply water and energy  |
| Electricity                          | kwh/ton                      | 200-256 | 200-256 |                                                                                |
| Labor                                | person                       | 1600    | 1600    |                                                                                |
| Red mud and tailing slurry discharge | million m <sup>3</sup> /year | 0.8     | 0.6     | Construct 500 ha landfill area with a capacity of 20-25 million m <sup>3</sup> |
| Long-term land use                   | km <sup>2</sup>              | 23      | 100     | 30-50 years for bauxite mining activities                                      |
| Displaced households                 | household                    | 1600    | 760     |                                                                                |
| Railway system                       | billion USD                  | 3.1     |         | Provide by the government                                                      |

**Table 2.** Development plan of bauxite mining in the Central Highlands.

| Projects      | Location               | Deposits                        | Capacity (million tonnes/year)             | Status            |
|---------------|------------------------|---------------------------------|--------------------------------------------|-------------------|
| Lam Dong 1    | Lam Dong               | Nam Phuong, Doi Thang Loi mines | 0.1                                        | Feasibility study |
| Lam Dong 2    |                        |                                 | 0.55                                       | Planned           |
| Tan Rai plant |                        | Tan Rai mine                    | 0.6                                        | Operating         |
| Gia Lai 1     | Gia Lai                | Mang Den, Kon Ha Nung Mines     | 1.5                                        | Planned           |
| Nhan Co plant | Dak Nong               | Nhan Co and neighbouring mines  | 0.3-0.6 (2007-2015)                        | Operating         |
|               |                        |                                 | 0.6-1.2 (2016-2025)                        |                   |
| Dak Nong 2    |                        | 1 May mine                      | 1.5-2.0 (2007-2015)<br>3.0-4.0 (2016-2025) | Planned           |
| Dak Nong 3    |                        | Gia Nghia mine                  |                                            |                   |
| Dak Nong 4    | Tuy Duc, Daksong mines |                                 |                                            |                   |
| Binh Phuoc 1  | Binh Phuoc             | Binh Phuoc's mines              | 1.5-2.0                                    |                   |

**Figure 2.** Bayer technology (Szépvölgyi J, 2011).

Technology has been applying in Tan Rai and Nhan Co plant will generate red mud in dry form. Red mud is moved to the disposal ponds by pipes and the sand is transported by truck. Two disposal ponds of each plant have been designed for more

than 30 using years (Huan T.M et al, 2017). Table 3 shows the composition and adherent liquor of the red mud from the Tan Rai and Nhan Co alumina refinery.

**Table 3.** Characterization of disposed red mud from Tan Rai and Nhan Co Alumina plants (Huan T.M et al, 2017).

| Red mud composition            | Tan Rai % | Nhan Co % | Adherent liquor composition                      | Tan Rai g/l | Nhan Co g/l |
|--------------------------------|-----------|-----------|--------------------------------------------------|-------------|-------------|
| Fe <sub>2</sub> O <sub>3</sub> | 46.10     | 46.32     | Na <sub>2</sub> O total                          |             | <3.5        |
| Al <sub>2</sub> O <sub>3</sub> | 16.91     | 17.056    | Na <sub>2</sub> O caustic                        | 4.6         |             |
| SiO <sub>2</sub>               | 6.60      | 6.70      | Al <sub>2</sub> O <sub>3</sub>                   | 4.8         | <3.0        |
| TiO <sub>2</sub>               | 5.48      | 7.20      | Solid content in under flow from the last washer | 550-650     | 550-650     |
| Na <sub>2</sub> O combined     | 3.06      | 3.43      |                                                  |             |             |
| CaO                            | 4.48      | 5.29      |                                                  |             |             |
| Others                         | 17.06     | 13.50     |                                                  |             |             |
| L.O.I                          | 11.70     | 11.71     |                                                  |             |             |

#### 4. Bauxite development policies and challenges

All minerals, which included fuel and all non-fuel minerals located within the Vietnam's territory and territorial water, are belong to the people and governed by the state. In Vietnam, all aspects of mining activities are governed by the Mineral Law (Law on Minerals No. 60/2010/QH12, 2010). In order to support this law and appeal investor interest in the mining industry, a series of legislations (The Mineral Industry of Vietnam, 2011, 2012, 2013, 2014) come into force, for example, Directive 02/CT-TTg (2012) outlines specifically the licensing process, or Dispatch No. 18228/BTC-CST (2014) announces a new tax rate on exporting natural resources...

Target to become one of leading aluminium production countries in the region and in the World, Vietnam Government has created favour conditions and prior policies to businesses and investors interested in bauxite exploitation and aluminium production (Phuong T.K, 2014). Decision No. 55/2007/QD-TTg (2007) identifies bauxite mining and the large-scale production of alumina in the Central Highlands is a national priority of the Vietnamese government to develop regional/national economy, and to transfer the economic structure of industrial proportion in GDP, taking part in giving Vietnam to become the country of developing industry at 2020. Vietnamese government considering bauxite mining

and alumina production is the priority industry for the 2007-2010 period, with a vision to 2020 (decision No. 55/2007/QD-TTg, 2007), with a number of approved incentive policies for this industry.

While the significant benefits from bauxite mining are visibly seen, such as the infrastructure improvement, and the development of local economy, potentially adverse impacts on the environment, society, and especially national security and defense could seriously undermine these economic potentials. Tran H.M (2012) shows the strong concerns of scientists, environmentalists and organizations on these negative impacts. Morris J (2013) reviewed some of the key debates and concerns that emerged around the Master plan, comprising: land loss, deforestation and soil contamination; displacement of local and indigenous communities; "red mud" and mining waste; water and energy consumption; technology, management and financing... Therefore, the fullest investigation of the mentioned negative impacts for mining bauxite and producing alumina is an imperative duty to scientists, environmentalists, experts and the government for structuring economy and formulating policies.

#### 5. Conclusion

Holding the world's third-largest bauxite reserves, Vietnam is available to become a major aluminum producer. This is also a very favorable condition for the development of the mining industry in particular

and the development of the country's economy in general. However, it is necessary to fully assess the negative aspects of bauxite mining in the Central Highlands for the sustainable development.

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